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MANUAL

FOR THE

ARTILLERY ORIENTATION OFFICER

1917

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MANUAL

FOR THE

ARTILLERY ORIENTATION OFFICER

CONSISTING OF

EXTRACTS FROM "MANUEL DE L'OFFICIER ORIENTEUR D'ARTILLERIE," A FRENCH OFFICIAL MANUAL CONTAINING A REPORT OF CONFERENCES HELD IN THE ARMY CENTERS OF INSTRUCTION FROM NOVEMBER, 1916, TO FEBRUARY, 1917

Translated by the Army War College in collaboration with the United States Geological Survey and the United States Coast and Geodetic Survey

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WAR DEPARTMENT.
Document No. 684.
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WAR DEPARTMENT,
WASHINGTON, *November 20, 1917.*

The following Manual for the Artillery Orientation Officer is published for the information of all concerned.

[062.11, A. G. O.]

BY ORDER OF THE SECRETARY OF WAR:

JOHN BIDDLE,
Major General, Acting Chief of Staff.

OFFICIAL:
H. P. McCAIN,
The Adjutant General.

WAR DEPARTMENT,
THE ADJUTANT GENERAL'S OFFICE,
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MANUAL FOR THE ARTILLERY ORIENTATION OFFICER.

CHAPTER I.

ELEMENTS OF CARTOGRAPHY.

REPRESENTATION OF THE EARTH'S SURFACE ON A PLANE.

Maps, which are the basis of the study of a terrain and of various topographic measurements, are plane representations of parts of the earth's surface. If this surface were flat it could be represented as a whole on a plane on some definite scale. But since, as is well known, it is very nearly an ellipsoid of revolution it can not be developed on a plane surface without resorting to either tearing or folding. In the representation of it as a plane there will therefore always be some distortion either of angles or of distances, or of both. These distortions will be completely negligible if the surface to be represented is small, for that surface is then indistinguishable from a plane tangent to the center of the small area represented. The plane representation of such a small area is a map. It was such areas that were especially considered in the maps prepared before the present war, particularly in connection with artillery work. Accurate large-scale maps accordingly were prepared for limited areas around fortified towns, for which the distortions are negligible.

The extension of the use of accurate maps over the whole length of the battle front has led to a consideration of the distortions involved in the various methods of representing the earth's surface. It became necessary to find for the new

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maps a single system that could be applied throughout the zone of military operations and that would involve in the whole region covered only such angular and linear distortions as are permissible from the artillerist's point of view.

GEOGRAPHIC COORDINATES.

Any point on the surface of the earth is defined by the intersection of the meridian and the parallel that pass through it. The *longitude* of a point is the angle made by the plane of the meridian passing through this point with the plane of the prime or initial meridian taken as the origin of longitude—in France, the meridian of Paris. Longitude is reckoned from 0 to 200^g [grads, French "grades"[1]], positively toward the west, negatively toward the east. The *latitude* of a point is the angle made by a line drawn normal to the surface at this point with the plane of the Equator. Latitude is reckoned from 0 to 100^g, positively in the Northern Hemisphere, negatively in the Southern. The longitude and latitude of a point are its *geographic coordinates.*

SYSTEMS OF PROJECTION.

GENERAL PRINCIPLES.

In making a map each point on the earth's surface is represented by a corresponding point on the plane surface according to a definite method or *system of projection.* It is convenient to draw first the parallels and meridians corresponding to round numbers—one for every 10 minutes, for example. A point whose geographic coordinates are known can then be located on the map by interpolation, and inversely the geographic coordinates of a point can be derived from its position on the map. The character of the network of meridians and parallels on a map depends on the system of projection used. There are many systems of projection. The choice of a system is determined by

[1] A grad is a unit in the centesimal system of angle measure equal to one one-hundredth of a right angle. (See p. 38.)

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the use for which the map is intended; the question is whether it is desirable to preserve the angles undistorted or to preserve the areas undistorted, whether it is desirable to preserve as

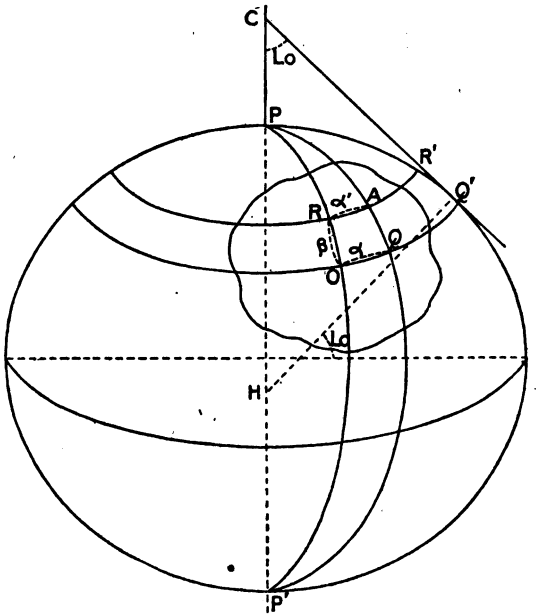

FIGURE 1.—Location of points on the earth's surface by geographic coordinates.

nearly as possible angles undistorted and also distances undistorted along a meridian or a parallel, or whether it is desirable to have an equal amount of distortion in both directions.

Let us study Bonne's projection; the polyhedral projection, used for maps made before the war; and Lambert's projection, adopted for the new battle maps. (See fig. 1.)

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Let O be a point whose geographic coordinates are L_o, M_o, located at the center of the area to be represented and taken as origin of the projection.

Let POP′ be the meridian passing through O, whose longitude is M_o, and OQQ′ the parallel of latitude L_o.

Let A be any point whose coordinates are L and M, located on the meridian PAP′ and on the parallel RAR′.

Let a be the length of the parallel of O included between the two meridians.

Let a' be the length of the arc of the parallel of A included between the two meridians.

Let β be the length of the arc of the meridian included between the two parallels.

Let $N_o = HQ'$ be the length of the normal to the surface at the parallel of O.

BONNE'S PROJECTION.

The meridian of O (fig. 2) is represented by a straight line *co* and the parallel of O by a circle whose center is at *c* on the line *co*, and whose radius is $co = CQ' = N_o \operatorname{cotg} L_o$. Lay off on *oc* in the proper direction from *o* a length *or* equal to β. The circle with the center *c* and radius *cr* will represent the parallel of the point A. Lay off upon this parallel a length $ra = a'$, and the point *a* will then represent on the map the point A of the earth's surface. If upon the circle representing the parallel of O we lay off $oq = a$, and join all points, such as *a* and *q*, whose longitudes are equal, we shall have the meridian of A upon the map. It may be proved that the angle between the tangent to the meridian at *a* and the initial meridian of the projection has for itc value $(M - M_o) \sin L$. This is the convergence of the meridians.[1]

[1] This formula is approximate only but is an excellent approximation for points within a few grads of the initial meridian of the map.—Translator.

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In this projection parallels are represented by concentric circles, the distances between which are equal to the lengths of the arcs of the meridian upon the spheroid. The meridians are curves meeting in a point p such that op=arc OP. In this projection angles are preserved undistorted; also lengths along the initial parallel and meridian. Departure from them brings in distortions which at the edges of the map of France reach a

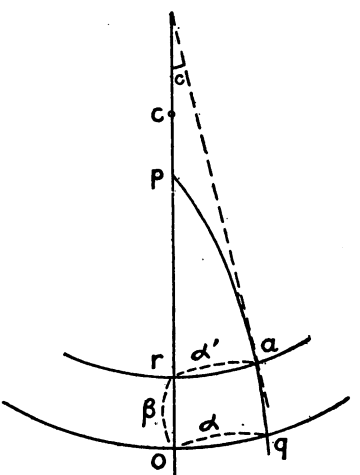

FIGURE 2.—Bonne's projection.

value of 18′ for angles and $\frac{1}{175}$ for lengths, distortions which are not negligible in the preparation for artillery fire and which are inadmissible in computations.

On Bonne's projection there have been made—

1. The map on the scale of 1:80,000, called the staff map, and the enlargement of it in black on the scale of 1:50,000, and the map of France on the scale of 1:200,000. $L_o=50^g$ and $M_o=0^g$ (meridian of Paris).

2. The Belgian maps on the scales of 1:20,000, 1:40,000, and 1:100,000, for which $L_o=56^g$ and $M_o=2.2605^g$ east of Paris (meridian of Brussels Observatory).

3. The battle maps for a small number of the armies, for which the transfer to the Lambert system has not yet been finished.

POLYHEDRAL PROJECTION.

The region to be represented is divided into a certain number of small areas, each bounded by two parallels and two meridians. Each one of these areas is represented separately on the assumption that it is indistinguishable from the plane tangent at its center, an assumption which amounts to replacing the earth by a body having many quadrangular facets. Each of these facets will be represented by an isosceles trapezoid having for its bases the straight lines representing the two limiting parallels and for its sides the straight lines representing the two limiting meridians. Each base and east side is then divided by points into equal parts, and the network of parallels and meridians is formed by straight lines joining these points. Within each one of these maps angles and distances are preserved practically true. It is not possible to fit together this series of maps to make up a map of the region. Nevertheless, the "play" of the paper makes it possible, in practice, to fit together a certain number of these maps.

The polyhedral projection is used—

1. In France, for the battle maps of fortified towns on the scales of 1:10,000 and 1:20,000 and for the map on the scale of 1:50,000, in colors.

2. In Germany, for maps on the scales of 1:25,000 and 1:100,000.

LAMBERT'S PROJECTION.

The initial meridian and parallel (fig. 3) are represented as in Bonne's projection. The meridians are represented by straight lines radiating from C at intervals proportional to the

longitude and a is the arc of the initial parallel laid off on the circle of radius CO, as in Bonne's projection. The other parallels are also represented by circles with center at C, spaced in such a way as to make the projection conformal—that is, to preserve angles unchanged.[1]

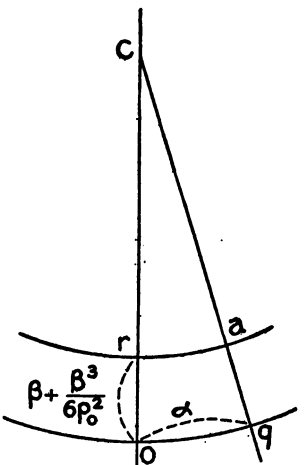

FIGURE 3.—Lambert's projection.

It can be proved that in order to realize this condition the spacing of the parallels should be equal to

$$\beta+\frac{\beta^3}{6\rho_0^2}$$

β being the arc of the meridian reckoned from O, and ρ_0 the mean radius of curvature of the ellipsoid at the origin O. The

[1] This is exactly true only for points within short distances from the point of origin if the approximate formula given is adhered to. If the less simple but more exact formula is used the projection is exactly conformal.—Translator.

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distortion in the element of length is, then [1]—

$$\frac{\beta^2}{2\rho_0^2}$$

In this projection angles are preserved true.[1] Distances are preserved undistorted along the initial parallel but are distorted along the meridian and along the other parallels. The distortion is the same along the whole length of the parallel. This system is therefore suitable for a region extending along the parallels, as does the presumed theater of operations in northeastern France. It has been adopted for the battle maps of the armies, and its origin has been fixed at

$$L_o = 55^g \text{ and } M_o = -6^g \ (6^g \text{ east of Paris}).$$

This point is near Trèves.

On this projection the angle between the meridian of a point A and the initial meridian (the convergence of meridians) is equal to $(M - M_o) \sin L_o$ or, with the origin adopted, equal to $(M + 6^g) \sin (55^g)$ which, since $\sin 55^g = 0.76$ nearly, is equal to $0.76\ (M + 6^g)$. Distances are increased as we depart from the initial parallel in either direction, the unit of length in the projection changing from the value 1 to $1 + \frac{\beta^2}{2\rho_0^2}$. But by reducing the scale of the projection in a constant ratio m (nearly unity) the distances near the initial parallel are diminished. They are then preserved upon two parallels equidistant from the initial parallel and increased beyond them. With the factor $m = 1 - \frac{1}{2037}$, adopted for Lambert's projection as used at the front, lengths are preserved on the two parallels 53^g and 57^g, situated 2^g on either side of the initial parallel.

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[1] See footnote on p. 21.

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THE FRAMEWORK OF MAPS.

The topographic surveys that culminate in the making of a map require the previous determination of points of reference, which serve as a framework. This framework is supplied by geodesy. Reduced to its simplest terms, a geodetic framework consists of a certain number of points connected to form a net of triangles. Astronomical observations give the position of a vertex which serves as the point of departure and the azimuth of one side of a triangle starting from this point. The length of this side is measured and serves as an initial base line. The angles of the net are measured, and from these angles the positions of all vertices of the net are computed by trigonometry.

In practice all vertices of the net are not determined with the same precision. The skeleton of the triangulation of a large area is formed by chains of large triangles called primary triangles, whose sides are 40 to 50 kilometers or more. Their angles are measured with maximum precision; the mean error of an angle does not exceed 2 or 3 centesimal seconds. (See p. 38.) These chains by the first order are supported not by a single initial base but by several bases, which are measured in different areas and which serve as checks for the triangulation. The accuracy of the geodetic base measurements is of the order of 1 : 1,000,000.

The spaces included between the principal chains are filled with triangles of the first order. The triangles of the first order are filled with smaller triangles, which are based on the first and the vertices of which are called points of the second order. The angles of the triangles of the second order are measured with an accuracy of about 10 centesimal seconds.

Finally, from all points of the first and second order sights are taken to prominent points (natural signals, steeples, etc.) without occupying them. These points obtained by intersection are called points of the third order.

Points of the first order are fixed within 2 or 3 decimeters; those of the second order within about 0.5 meter; those of the

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third order within 1 or 2 meters. The geodetic points of the first, second, and third orders form the framework or general control on which are based all topographic surveys that go to the making of maps. These surveys always begin with the formation of a supplementary net or control based on these geodetic points but with smaller meshes. This detailed control is obtained by primary traverse executed with the tachymeter and computed, or is obtained graphically by topographic methods. In the terminology of the Geographic Service the surveys that have as their purpose the determination of isolated points are called *topometric surveys; topographic surveys*, properly speaking, have to do with the delineation of objects and of the forms of the terrain. For simplicity the name *topographic surveys* is applied to all graphic construction, whether made on an accurate map or on a plane-table sheet, starting from the known control points and intended to serve for the organization of artillery fire.

SYSTEM OF SQUARES ON THE MAPS.

Rectangular coordinates.—When the map of an area has been laid out according to any system of projection, two rectangular axes with an arbitrary origin may be drawn on it and the map laid off in squares parallel to these axes, every square measuring 1 kilometer on each side. A point a of the map will then be fixed accurately and unambiguously by its rectangular coordinates x and y, the distances of this point from the two axes oy and ox, which are taken as origins of measurement. There is no necessary a priori relation between the projection of a map and the system of squares applied to it. Nevertheless there is a practical advantage in choosing a system of squares in which the calculation of points is easy, so that, instead of fixing the origin and the direction of the axes arbitrarily, it is well to fix them in such a way that there is a simple relation between these elements and the elements that define the

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projection itself—for example, to fix the origin of the system of squares at the center of the projection and to take as the axis of y the straight line that represents the meridian of the projection.

The rectangular axes being defined analytically with reference to the system of projection, it is possible, when we know the geographic coordinates L and M of a point A of the earth, to calculate the rectangular coordinates x and y of the corresponding point of the projection, and, inversely, when we know x and y, to deduce L and M.

When the map of a region has been made according to one system of projection it is possible to find the rectangular coordinates of a point of this map according to another system of projection, provided, of course, that the analytic or geometric definitions of the two systems of projection and of the two systems of squares are known.

System of kilometric squares on Lambert's projection, in use at the front.—The Y axis (fig. 4) is the straight line which represents the initial meridian -6^g, and the X axis is the tangent to the circle which represents the parallel 55^g at its point of intersection with the Y axis. The point a of the projection will be defined by x and y. In order not to have negative coordinates, the point o is given the coordinates

$$X_o = 500{,}000 \text{ meters.}$$
$$Y_o = 300{,}000 \text{ meters.}$$

The coordinates of a will be

$$X = 500{,}000 + x.$$
$$Y = 300{,}000 + y.$$

The meridian of the place at the point a makes with the y axis an angle equal to the convergence of the meridians $= (M + 6^g) \times 0.76$, with sign such that the direction corresponding to geographic north shall converge toward the initial meridian of -6^g.

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Example: The map on the scale 1:80,000 is issued in rectangular sheets representing areas measuring 64 kilometers east and west by 40 kilometers north and south. The vertical border is parallel to the meridian of Paris. What will be the inclination of the y axis of the system of squares on Lambert's projection to the vertical line of the border?

This angle $c_1 = (0+6^g) \times 0.76 = 4.56^g$ toward the west.

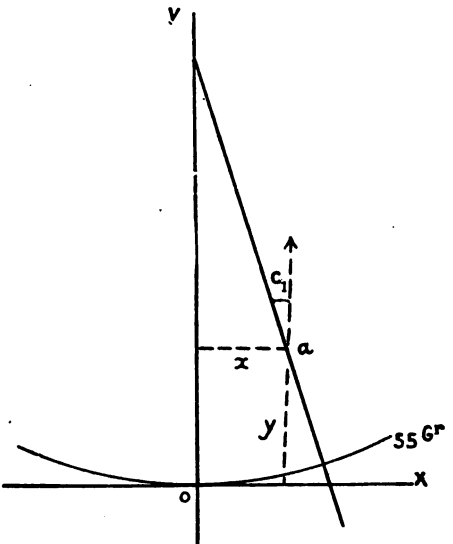

FIGURE 4.—System of kilometric squares on Lambert's projection.

System of squares peculiar to certain armies.—Certain armies still have their battle maps made on the Bonne system. The axes of the system of squares adopted are then the straight line representing the initial meridian M_o and the line tangent at that meridian to the circle representing the parallel 50^g. At the

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boundary between two armies one of which has the Bonne system of squares and the other the Lambert system the same target has different rectangular coordinates. This inconvenience is serious, the more so as the limits of the armies are subject to variations and as the army which finds itself assigned to a new portion of the front is obliged to make afresh, for this portion, a new battle map with a new numbering of targets.[1] The adoption of the Lambert system for the entire front will do away with this inconvenience.[2] It was, moreover, imperative to adopt a single system in order to prepare in advance squared maps, so that the same system used in the present battle maps could be maintained later for all armies.

[In artillery orientation it is found convenient to use azimuths referred to the y axis of the system of squares ruled on the maps. Such azimuths will in this book be called *axial bearings* and must not be confounded either with azimuths as commonly reckoned or with magnetic bearings. Axial bearings, here sometimes more briefly called bearings, are reckoned from 0 to 6,400 mils (or from 0 to 400 grads) in clockwise direction from the north end of the y axis to which they refer.]

MAPS OF FRANCE AND FOREIGN MAPS ON DIFFERENT SCALES.

MAPS OF FRANCE.

Map on the scale of 1: 80,000, in black.—This map is derived from surveys executed on the scale of 1: 40,000. It is called the staff map and was undertaken at the beginning of the nineteenth century. Its completion has required about 60 years.

[1] Maps were even at one time made on the Bonne system according to spherical lunes—that is to say, with different origins, spaced 2^g apart—the purpose of which was to avoid the distortions due to this mode of projection, but it is plain that these diverse origins were sources of serious inconvenience at the boundaries of the lunes.

[2] In the period of transition before the Lambert system of squares is generally adopted certain maps have two systems of squares.

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It covers the whole of France and Alsace-Lorraine but has not been kept up to date in the annexed territory. It is made on the Bonne projection (L_o=50^g, M_o=meridian of Paris). Each sheet is divided into four parts, each 25 by 40 centimeters, representing an area measuring 20 by 32 kilometers. At each corner are given the geographic coordinates and the rectangular coordinates referred to the center of projection. The geodetic points are fixed with considerable accuracy; the error of the other points may reach 100 meters.

Map on the scale of 1: 50,000, in black.—This is a photographic enlargement of the map on the scale of 1: 80,000; it is consequently of the same accuracy. It is this map, which is easier to read than the 1: 80,000 one, that is laid off in squares on the system of projection adopted (Lambert's).

Maps on the scale of 1: 10,000 and 1: 20,000, in black.—These are the former battle maps of fortified towns. The maps on the scale of 1: 10,000 are the results of precise surveys made on the ground on a scale of 1: 10,000. The projection is polyhedral. The elevations accord with the general level system of France. The usual contour interval is 5 meters, but for level regions it is 2.5 meters. Each sheet of the 1: 10,000 map includes an extent of 5 centesimal minutes in latitude and longitude. The maps on the scale of 1: 20,000 are obtained by photographic reduction from those on the 1: 10,000 scale. Each sheet on the 1: 20,000 scale includes four sheets on the 1: 10,000 scale, not fitted together but simply placed side by side, with intervals between them. It follows that these maps can not be used in the ordinary way for every purpose, particularly not for the measurement of angles and of distances.

The accuracy of the maps on the scales of 1: 10,000 and 1: 20,000 is variable. It may be assumed that, for moderately rolling country, points are exact within 10 meters in position and within 5 meters in altitude.

Maps on the scale of 1: 50,000, in colors.—These maps are made by means of surveys on a scale of 1: 10,000 in level dis-

tricts and in moderately rolling country and by means of surveys on a scale of 1:20,000 in mountainous country. The projection is polycentric (polyhedral). Each sheet represents an area 20 centesimal minutes in latitude by 40 in longitude, which for the northern zone corresponds to dimensions of 0.40 meter by 0.50 meter approximately (8 sheets of the map on the scale of 1:20,000 or 32 sheets of the map on the scale of 1:10,000). The relief is shown by contours representing vertical intervals of 10 meters, supplemented by shading [stumping, as in crayon drawing]. The maps are printed in eight colors. These maps, of which there are only a small number of copies, are in course of preparation.

Map on the scale of 1:200,000, in colors.—Derived from the map on the scale of 1:80,000. Each sheet corresponds to four sheets of the 1:80,000 map (80 by 128 kilometers). The relief is shown by contours representing vertical intervals of 40 meters, with 20-meter contours inserted in level regions, and principal contours every 200 meters, supplemented by shading [stumping]. These maps are printed in six colors.

A new set (1912) has the following improvements: Settlements are represented in detail, windmills, factories, forest ranger's quarters, chateaux, etc., being indicated. Only the highways and roads passable by vehicles are shown in red. The dirt roads and paths are shown in black. The population of the communes is given by the number of hundreds of inhabitants. Bridges and fords are indicated by special conventional signs. The relief is shown by contours representing vertical intervals of 20 meters, heavier principal contours representing intervals of 200 meters.

MAPS OF BELGIUM.

Map on the scale of 1:20,000.—Compiled from land-title (cadastral) maps, reduced to a scale of 1:20,000, and verified and completed on the ground. Bonne's projection for the meridian of

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Brussels and the parallel of 56° is used. The relief is shown by contours representing vertical intervals of 1 meter on the left bank of the Meuse and 5 meters on the right bank. Printed in black. Certain of the field sketches have been enlarged to the scale of 1:10,000.

Map on the scale of 1:40,000.—Made by assembling and reducing the sheets of the 1:20,000 map. Contour interval is 5 meters. Printed in black. A new edition is published with watercourses in blue and roads in red.

Map on the scale of 1:100,000.—Reduced from the 1:40,000 map. Each sheet includes two sheets and two half sheets of the 1:40,000 map. Contour interval is 10 meters. Printed in six colors.

MAPS OF GERMANY.

Plane-table sheets on the scale of 1:25,000.—Reproduced from the original surveys on the scale of 1:25,000, made for the purpose of preparing a general map on the scale of 1:100,000. Polyhedral projection. The prime meridian is the meridian of the Island of Ferro, which, by convention, is taken to be exactly 20 sexagesimal degrees west of the observatory of Paris. The area of each sheet is 6 sexagesimal minutes in latitude and 10 minutes in longitude (about 144 square kilometers).

The relief is shown by contours representing vertical intervals of 10 meters in very rolling country and 5 meters in slightly rolling country, with intermediate contours of 2.50 meters and even 1.25 meters on gentle slopes; principal contours every 20 meters. The contours are numbered at the borders and along their courses. Printed in black; water colored blue. These sheets, commonly called *plane-table sheets* [planchettes], have been issued for a large part of Germany, including Alsace-Lorraine and the Rhine Provinces.[1] Their accuracy is com-

[1]All the Alsace-Lorraine sheets have been enlarged to the scale of 1:20,000 by the Geographic Service and printed in black.

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parable to that of the French map on the scale of 1:20,000, as regards planimetric detail, but the relief is less exact, especially in broken country.

Map on the scale of 1:100,000.—Formed by the reduction of the plane-table sheets on the scale of 1:25,000. Each sheet covers 15 sexagesimal minutes in latitude and 30 minutes in longitude. Numerous and detailed conventional signs. Relief is shown by hachures normal to the contours. Two scales are given at the lower border—one in meters and in paces, the other in geographic miles. Printed in black.[1]

BATTLE MAPS AND REVISIONS OF BATTLE MAPS.[2]

Battle maps are maps on a large scale (1:20,000, 1:10,000, or 1:5,000), on which are shown the enemy's works and certain of our own defensive or offensive works. These maps have the same official standing as the staff maps. They are to be accepted, to the exclusion of all other documents, as authority for the names to be used in orders, instructions, and reports.

Preparation of battle maps.—Battle maps are prepared in the armies by range triangulation detachments [groupes de canevas de tir]. In regions for which there are maps on the scale of 1:10,000 (French territory) or on the scale of 1:20,000 derived from accurate surveys (regions represented on the maps above given for French territory, plane-table sheets of Alsace-Lorraine, map of Belgium on the scale of 1:20,000), these maps form the basis of the battle maps. They are generally collected in the most convenient form (for example, in a group of eight quarter sheets of the 1:20,000 scale without interspaces), or in a form that best fits the needs of the Army, and are usually redrawn in order to make them more legible.

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[1] A map on the scale of 1:50,000, in black, has been made by the Geographic Service by enlarging the map on the scale of 1:100,000.

[2] See "Instructions concerning battle maps of Feb. 14, 1916" [Instructions sur les plans directeurs du 14 février 1916].

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In regions for which there is no accurate map on a large scale the battle map is prepared by assembling the land-title (cadastral) maps with the scale of 1:10,000 on a system of squares showing the geodetic points. Furthermore, all material (plans of railroads, canals, large estates, etc.) capable of contributing to the accuracy and definiteness of the map is used. The planimetric detail is brought up to date by photography. The contours are obtained by enlarging the field sketches obtained by the survey on the scale of 1:40,000 that have served as a basis for the hachuring on the 1:80,000 map. The degree of accuracy thus obtained is necessarily variable. Though fairly good, as a rule, for the planimetric detail, it is only roughly approximate as regards the features of the terrain. Nevertheless, in certain armies regular surveys on the scale of 1:10,000 or 1:20,000 have been undertaken by the range triangulation detachments and carried forward within our lines wherever it was possible. The maps for these areas are excellent. The location of the various works on the battle maps is for the most part obtained from photographic data. Some of these surveys, being long and difficult, can not be performed accurately except by a special personnel having long professional experience with problems of geometry and cartography.

Features represented on battle maps.—The planimetric detail includes all information generally shown on large-scale maps. The "Appendix to the instructions concerning battle maps" [l'Annexe à l'instruction sur les plans directeurs] contains a list of the conventional signs adopted. The German works, which are very numerous (trenches, passageways, wire entanglements, machine guns, trench artillery, batteries, commander's posts, railroads, trails, etc.), can not all be represented on all scales without making the reading of the maps difficult. A selection is therefore made according to their importance. The advance line of the French works is shown in all detail compatible with the scale, particularly with the scale of 1:5,000, on which numerous reference points are needed in order to ob-

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tain accurate locations. The maps showing French trenches give the trenches and communication trenches, with all the names and numbers used in the sectors to designate them. Published maps should never carry any data regarding armament (machine guns or batteries), wire entanglements, or similar works, or regarding the organization of the command or the order of battle of the troops occupying the sector.

Names and designations.—The experience of the present war has shown that it is well to multiply greatly the names and designations on the battle maps. The names adopted for the planimetric detail are those of the staff maps, the names of the land-title (cadastral) survey, the names used in the sectors, or, if these are lacking, arbitrary names.

Numbering the targets.—The various details of the enemy's works are named and numbered. Important points in the trenches are designated by three-figure numbers or by their coordinates in hectometers to four figures. Batteries and possible emplacements for batteries are designated by their coordinates in hectometers to four or to six figures. The new names or designations introduced by the different corps or services in their special documents do not become authoritative until they have been adopted by the range triangulation detachments and entered upon the maps published under their supervision.

Revisions of battle maps.—The topographic sections of the army corps have as their principal duty the preparation of revisions of the battle maps, the frequent printing of which (every day in periods of activity) insures that the battle map is kept up to date in the interval between successive editions. The topographic sections of the army corps use as a basis for their revisions the battle maps on the various scales prepared by the range triangulation detachments or the enlargements of these maps. During an active period the rapidity with which these revisions must be prepared necessarily makes their accuracy rather variable. The topographic sections of the army

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corps are assisted by the divisional topographic sections, which are especially intrusted with executing upon the ground all reconnaissances and topographic surveys necessary to verify and to work up the maps.

Distribution, preservation, and destruction of battle maps.—The topographic sections of the army corps have also the important task of attending to the distribution of the battle maps—of seeing that the persons who should be provided with them have received them and that the special instructions relative to their use, their preservation, and their destruction have been carefully observed. The range triangulation detachments transmit to the topographic sections of the army corps the number of copies which they need and see that these are renewed. The battle maps, on various scales, that show only the German works should be distributed in the artillery down to battery commanders, inclusive. The distribution of battle maps showing French trenches is limited to battalion commanders. The battle maps showing French works must not be taken to the first-line trenches, and it is desirable to reduce as much as possible the features of our works that need to be shown on the ordinary battle maps in use on the first line. Furthermore, all battle maps and all revisions of them should be considered confidential documents, which may give the enemy valuable information, such as our knowledge of his works, the topography of the region within our lines, or the exact position of points of reference which may be useful to him. Obsolete copies should be burned by those who have them.

DOCUMENTS OTHER THAN TOPOGRAPHIC MAPS AND BATTLE MAPS.

Aerial photographs.—Aerial photographs are now distributed to the artillery in fairly large numbers. These photographs are used in preparing battle maps or their revisions by the range triangulation detachments, the topographic sections of the army

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corps, and the divisional topographic sections. Artillery officers therefore need make plan projections from photographs only exceptionally, to enable them, before the arrival of the revision material, to interpolate a few details among the plan projections already made. For these partial projections the simplest methods are the best, such as constructions by alignment. Gross errors will be avoided by noting particularly—

1. That a photograph from an airplane is not a mere enlargement or reduction of the map. Its scale varies from point to point, and at any given point it varies with the direction of the view.

2. That, in moderately broken country, errors arising from the relief of the ground, even in photographs taken almost horizontally, are far from negligible.

3. That finally, and above all, great care must be used in the choice of reference points. A sufficient number of them must be taken, and the reliability of each of them must be known.

Though the orientation officers rarely have to make plan projections from photographs they should nevertheless study minutely the photographs themselves, should seek in them all details concerning targets, should endeavor to know their precise meaning and interpretation, and should compare photographs of different dates. This study is treated in another chapter. It is, moreover, absolutely essential to coordinate the results of this study with those obtained by other methods of observation and with information collected in other ways.

Lists of the points of the general control.—Lists of the points of the general control are prepared and distributed to the artillery by the range triangulation detachments. They include—

1. The geodetic points of the first, second, and third order, taken from the triangulation of the Geographic Service.

2. Supplementary geodetic points, fixed by regular geodetic methods, starting from the above-mentioned points and comparable in precision to the points of the third order.

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3. Points of computed traverses made with the theodolite or tachymeter in wooded regions where triangulation does not provide a sufficient density of points.

It is the duty of the range triangulation detachments to prepare the general control sheets, on which are based the surveys of all points useful to the artillery. These surveys are made—

1. As far as they deal with the positions of batteries and observation stations and the aiming of guns, by regular topographic methods, this duty devolving on the orientation officers and battery commanders.

2. As far as they deal with the enemy's positions, partly by regular geodetic and topographic methods, but particularly by working up photographs taken from airplanes. This work falls almost entirely on special branches—range triangulation detachments, topographic sections, artillery information service, and artillery observation sections.

On the parts of the front for which there are available large-scale maps (1:20,000 or 1:10,000), derived from accurate surveys made in times of peace, the artillery surveys can often be based directly on the battle maps. Nevertheless, the general control sheets are necessary—

1. To increase the density of points of reference in the regions occupied by our batteries, for the original points of reference shown on the maps (steeples, windmills, isolated houses) are generally destroyed. Even the planimetric details of the map are not always sufficiently close together to serve as a basis for surveys which must be both simple and rapid. Furthermore, in the region of the first positions these planimetric details may have disappeared more or less completely.

2. To serve as a basis in preparing an accurate system of reference points in the region of the enemy's first position for use for fire (on auxiliary targets, etc.), and also to facilitate the organization of the fire of our artillery after its first rush forward following an attack—an extremely important matter.

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3. To permit the checking of the map in certain parts where it might be in error because of changes that have occurred since the latest revision (outlines of wood, roads, etc.).

Daily bulletin of information.—Finally the artillery information service, whose duties have been defined in a recent order, should "communicate to the subordinate commands of artillery and to the units all accurate information which it has been able to obtain about targets. It should do this by a daily bulletin distributed down to battery commanders, inclusive."

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CHAPTER II.

ANGULAR MEASURE AND MAGNETIC DECLINATION.

SYSTEMS OF ANGULAR MEASURE.

1. Degrees:
   Circumference=360°.
   Quadrant of the circle=90°.
   1°=60′=3,600″; 1′=60″.
2. Grads:
   Circumference=400^g (grads).
   Quadrant of the circle=100 grads.
   1 grad=100 centesimal minutes (100′)[1]=10,000 centesimal seconds (10,000″); 1′=100″.
3. True mils (1 mil=angle subtended by 1 meter at a distance of 1,000 meters):
   Circumference=6,283.2 mils.
   Quadrant of the circle=1,570.8 mils $\left(1{,}570.8=1{,}000\,\frac{\pi}{2}\right)$.
4. Mils (1,600 system):
   Circumference=6,400 mils.
   Quadrant of the circle=1,600 mils.
5. Mils (Rimailho system):
   Circumference=6,000 mils.
   Quadrant of the circle=1,500 mils.

[1] To distinguish the minutes and seconds in the centesimal or grad system from the minutes and seconds in the sexagesimal or degree system, the accents placed to the right of the figures are reversed.

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RELATIONS BETWEEN DEGREES, GRADS, AND MILS (1,600 SYSTEM).

1°=1 grad 11ᶜ 11ᶜᶜ=17.78 mils (1,600 system).
1′ (sexagesimal)=1.85ᶜ (centesimal)=0.30 mil.
1 grad=0° 54′=16 mils (1,600 system).
1ᶜ (centesimal)=32″ (sexagesimal)=0.16 mil.
1 mil (1,600 system)=3′ 22.5″=6.25ᶜ.

The German artillery uses, for field artillery, mils (1,600 system); for heavy artillery, $\frac{1}{16}$ degree—that is, the circumference equals 5,760 of these units; the quadrant of the circle equals 1,440.

MAGNETIC DECLINATION.

The magnetic declination at a point where there is no local deviation is the angle which the magnetic needle there makes with the geographic north—that is, with the direction of the meridian of the place. The magnetic needle gives the direction of the magnetic north, which, in France, is to the west of the geographic north. The declination varies—

1. From one locality to another. The isogonic chart (Pl. I) opposite page 40 gives the declination at different localities for January 1, 1917. The declination increases on an average 0.72ᶜ per kilometer from east to west and 0.18ᶜ per kilometer from south to north. These are only rough average values. There are areas where the magnetic declination is anomalous, and in these areas there is said to be local deviation. Local deviation is due principally to masses of magnetic matter in the neighborhood of the needle. These masses may be unseen and unsuspected, such as deposits of magnetic iron ore, or they may be very obvious and avoidable, such as a wire entanglement, a gun, or an electric line. The magnetic effect of a wire entanglement or of a straight railroad track is negligible at distances greater than 10 meters. The effect of a piece of artillery is negligible at distances of 20 to 50 meters, the distance depending on the

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caliber of the piece, and the effect of an electric line is negligible at about 40 meters.

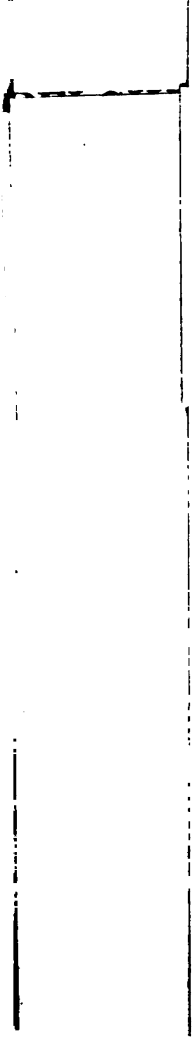
2. From one year to another. At present in northeastern France and adjacent territory the westerly declination is diminishing by about 16 centesimal minutes (16') a year. This rate appears to be increasing somewhat.

3. From one hour of the day to another. It takes on its mean value at about 10 o'clock and 18 o'clock. It is therefore well to orient instruments about these times. The diurnal variation is somewhat irregular and is much greater in summer than in winter. The maximum variations are the greatest in June, being $-5'(=-9')$ between 6 and 8 o'clock, and $+7'$ $(=+13')$ at about 14 o'clock; and are least in January, being $-1'$ $(=-2')$ at about 8 o'clock and $+4'$ $(=+6')$ at about 14 o'clock. Fuller details are given in the table on page 41, but it should be remembered that the table shows only the average diurnal variation. Slight departures from the tabular values may be expected at any time, and there are times when the magnetic needle is subject to large but transitory disturbances, extending over wide areas. These disturbances are known as magnetic storms.

USE OF ISOGONIC CHARTS.

The charts of magnetic declination (isogonic charts, Pls. I, II) for northeastern France and for western Germany have been prepared from somewhat old observations, reduced to the 1st of January, 1917, by comparison with corresponding observations taken at the magnetic observatories of Parc Saint-Maur and of Val-Joyeux. Under these conditions the lines of equal magnetic declination drawn upon them can be considered as accurate only within 20'.

To make use of these charts begin by marking the position of the locality. A simple interpolation between the two isogonic lines that include the point gives the declination for January 1, 1917. This first result is then to be corrected for secular variation and for diurnal variation. The secular variation for the



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regions represented upon the two maps is now about −16′ a year. The correction due to this variation is proportional to the time that has elapsed since January 1, 1917. To allow for diurnal variation apply to the result the correction taken from the following table for the month and hour of observation. This correction is zero a little after 10 o'clock and at about 18 o'clock. The unit of the table is the centesimal minute (′).

Average variation in magnetic declination at certain hours, by months.

Month.	6 h.	8 h.	10 h.	12 h.	14 h.	16 h.	18 h.
	′	′	′	′	′	′	′
January	0	−2	0	+6	+ 6	+2	0
February	−2	−4	−2	+6	+ 7	+4	0
March	−2	−6	−4	+7	+11	+6	0
April	−4	−9	−4	+9	+13	+6	0
May	−7	−9	−2	+9	+13	+6	0
June	−9	−9	−2	+9	+13	+7	+2
July	−7	−7	−2	+9	+11	+6	+2
August	−6	−7	0	+9	+11	+4	0
September	−4	−6	0	+9	+ 9	+4	0
October	−2	−6	−4	+7	+ 9	+4	0
November	0	−2	−2	+6	+ 7	+4	0
December	0	−2	0	+4	+ 6	+2	0

Example: Required the magnetic declination on February 20, 1917, at 14 o'clock at a place approximately in latitude 54° 39′, longitude 2° 97′ east of Paris.

	°	′
The chart (Pl. I) gives for this point 212 mils	13	25
The secular variation for 0.14 year=−16′×0.14		−2
The diurnal variation (table)		+8
Westerly declination	13	31

ORIENTATION OF A MAP BY COMPASS.

Battle maps, which generally show the direction of magnetic north, are oriented without difficulty. In dealing with a map that shows only the geographic meridians (map on the scale of 1:80,000, 1:50,000, or 1:200,000), place the compass or the

box needle in such a way that the magnetic needle is directed somewhat toward the west and makes with the meridian of the place, on the map, an angle equal to the axial declination of the place. If, exceptionally, the map gives simply a system of squares, not showing either a geographic meridian or the direction of magnetic north, calculate the angle of convergence of the meridian of the place with the initial meridian and add it to or subtract it from the axial declination, according as the place is to the east or west of the initial meridian. Place the map in such a way that the magnetic needle makes with the y axis of the system of squares the angle thus found. This angle of convergence for the Lambert projection adopted is equal to $(M+6^g)\times 0.76$.

In this formula M is the longitude in grads, west longitudes being considered positive. The numerical value of this correction x may be obtained by interpolating the table below. The correction (x) is to be added to the declination if the longitude of the place reckoned from Paris is greater than 6^g and is to be subtracted from the declination if the longitude is less than 6^g.

Longitudes	0^g / 12^g	1^g / 11^g	2^g / 10^g	3^g / 9^g	4^g / 8^g	5^g / 7^g	6^g
x	$4^g\ 56^c$	$3^g\ 80^c$	$3^g\ 04^c$	$2^g\ 28^c$	$1^g\ 52^c$	$0^g\ 76^c$	0

Thus, in the preceding example, for east longitude $2^g\ 97^c$, $x = 2^g\ 30^c$. The correction is subtractive. The angle between the magnetic needle and the y axis of the Lambert system of squares is therefore $13^g\ 31^c - 2^g\ 30^c = 11^g\ 01^c$.

In Bonne's projection the convergence of the meridians is equal to $(M - M_o)\times \sin L$, in which M is the longitude of the place, M_o the longitude of the initial meridian of the map, and L the latitude of the place. This expression contains three variables and is therefore not so readily tabulated as the preceding one but must be computed to fit each particular problem as it arises.

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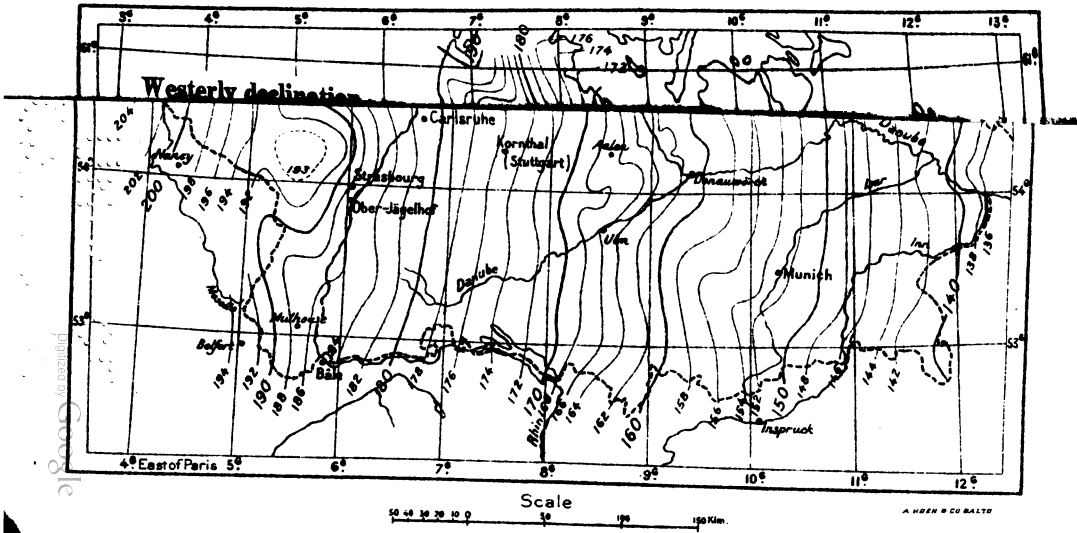
WESTERN GERMANY

MAGNETIC DECLINATION JANUARY 1, 1917

PLATE II



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CHAPTER III.

RECONNAISSANCE AND STUDY OF POSITIONS AND TARGETS.

The reconnaissance and the topographic studies which artillerists have to make on the ground or with the aid of maps deal either with the positions of batteries and the approaches to them or with the targets and their surroundings.

POSITIONS.

The most important topographic surveys made to determine the initial firing data of batteries are treated elsewhere (pp. 79–113). They should be performed as soon as possible, during the reconnaissance or during the installation of the batteries, before the first fire for adjustment by aid of the rounds themselves. The linking up with the terrain which such fire accomplishes can be effected more rapidly and easily by a few simple surveys. These surveys can be performed by the orientation officer or the battery commander, but in all circumstances the orientation officer of the battalion should have them in mind at the time of the first reconnaissance of the position and prepare for them.

Deflade.—The question of deflade comes up with regard to the emplacements of the batteries themselves and the approaches to them. The study of the map before any reconnaissances are made on the ground gives very useful information to one who is skilled in reading from the map the forms of the ground. This study of the map is really a study and not a mere examination. One should not be satisfied to form judgment about the features of the ground—the ridges, valleys, and slopes—by pre-

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possessions or by a single glance. If a contour map is at hand the contours should be studied attentively, their numbering read, their interval known, and the direction and numerical grade of the slopes considered. If in doubt, construct a section on an enlarged vertical scale. This preliminary study is easy and gives approximately correct results when it is made on a regular battle map. It is more difficult and less accurate when it is made on a map on a scale of 1:50,000, in which the relief is shown by hachures.

The results of this preliminary study of the map should then be checked and made accurate by a reconnaissance on the ground. In regard to battery emplacements, the observer should not limit himself to finding merely whether they are defiladed from terrestrial observation by the enemy and whether they are defiladed or not from his balloons. He should endeavor to give an accurate expression of this defilade in meters. For this purpose an instrument station should be set up, if possible, on the protecting ridge, approximately in the alignment of the battery and the enemy's position. Determine (by theodolite, clinometer rule, leveling alidade, compass goniometer, or binocular) the slope s' of the line from station to battery and the angle of site s of the enemy's position (both expressed in mils), measure or evaluate with all possible accuracy the distance from station to battery in meters, which we will call d, and calculate $\frac{d(s'-s)}{1,000}$, which is the value of the defilade in meters. When an approach is not completely defiladed, determine precisely the part which is not defiladed and designate the points of the enemy zone from which it is seen. Such points are often difficult to identify over the protective mask. To recognize them, a rapid glance at the map is not sufficient. It is necessary to get the direction carefully with the compass or, if necessary, with the plane table and compass. It will thus be possible to obtain accurate and definite information, which will enable the commander of the battalion or of the battery to arrange his movements with full knowledge of the situation.

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All useful data concerning defilade, the passability of roads, the condition of the ground, the obstacles, and the work of upkeep are shown on the battle map or on cross-section tracing paper attached to the battle map. A rapid sketch is always worth more than a long discussion.

Minimum range.—The same regard for accuracy should be applied to the determination of the elevation which will clear the mask. This determination is made in the way indicated farther on, under the heading "Determination of zones in the dead angle of fire." (See p. 68.)

TARGETS.

RECONNAISSANCE AND STUDY OF TARGETS.

The reconnaissance and study of targets is not merely a topographic operation; it is a tactical operation in the sense that it involves not only the location of the fixed elements of the enemy's works but also the quest for all data that will enable the observer to define the real character of the points or zones recognized, in so far as they are targets for artillery. What is considered here is only the duty of the orientation officer and of the officer of a battery. The summary discussion of methods for the precise determination of targets and the systematic search for all data which concern them (operations that are not in the line of work of the units) will be taken up in another chapter. For the orientation officer and for the officer of a battery the reconnaissance and study of targets may involve the following series of operations:

1. Determining on the map or on the ground the zones hidden from a definite observation station—that is to say, undertaking the location of visible and invisible areas.

2. Locating on the ground points of the region visible from a definite observation station and comparing them with those given on the map.

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3. Expressing graphically and recording the results of the above study on the ground, in the form of panoramic sketches.

4. Examining carefully on the ground, more or less continuously, a certain zone for the purpose of watching known targets or of discovering and determining the location of new targets. This is observation, properly so called.

5. Determining from the map the possibilities of fire of the batteries, which involves the study of counterslopes and the determination of the zones within dead angles.

6. Studying the targets from aerial photographs.

DETERMINATION OF VISIBLE AND INVISIBLE AREAS.

From the map.—If a regular contour map is at hand (for example, a battle map based on large-scale surveys), the location of visible and invisible areas may be determined with considerable accuracy by plotting on the map itself. This plotting will be less accurate if the relief on the map is inaccurate. In any case this work should be considered only a first approximation, which must be verified and made accurate by direct study on the ground. The method of determining graphically the visible and invisible areas consists in making sections of the ground based on the contours along vertical planes radiating from the point of view. These sections are constructed on a sheet of cross-section paper. For horizontal distances the scale of the map itself is used. These distances are transferred from the map to the cross-section paper with the help of a strip of paper. The vertical scale may be increased. For example, the side of a 5-millimeter square may be taken as representing 10 meters difference in level. The horizontal lines of the paper should be numbered accordingly.

It is unnecessary to construct the profile through the entire extent of the vertical section. For a profile analogous to that shown in figure 5 the work may be confined to the parts of the profile indicated by the full lines. The dotted parts need not

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be drawn. A first glance at the map shows that there are four successive ridges—(A), (B), (C), (E). (See fig. 5.)

Begin by constructing a profile of the upper part of the ridge (A). Then from the point of view O draw the tangent AA′ to this profile. The point of contact A is the boundary between a visible and an invisible area. All parts of the ground beyond A and below this line are invisible. By consulting the map it is seen immediately that the culminating point of the ridge (B) is certainly below AA′. This point is numbered 340 on the map, and at the distance of the ridge (B) the straight line AA′ reaches the height 350. The profile of the ridge (B) therefore

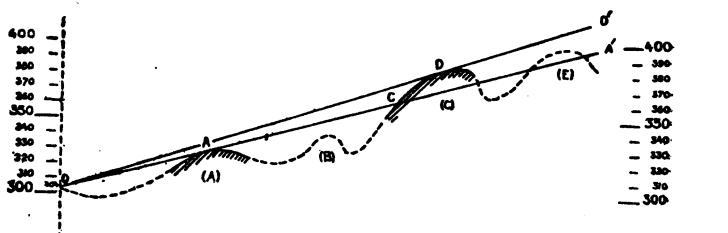

FIGURE 5.—Profile showing visible and invisible parts of terrain.

need not be constructed. It is easily seen also that the ridge (C) will overtop the line. Construct its profile. The point C, the intersection of this profile with AA′, is a second boundary between the visible and invisible areas. The point of contact D of the tangent ODD′ is the third point. Finally, it is seen without any construction that the ridge (E) is below DD′. It need not be constructed. To summarize, in the vertical section considered the ground is visible from O as far as A, is invisible from A as far as C, is visible from C as far as D, and is invisible beyond D.

The points A, C, and D are transferred to the map by their horizontal distances from the vertical through the point O. The boundaries between visible and invisible areas are thus

constructed by successive points. The invisible areas are shown by hachures made with a soft black pencil.

This construction takes into account only the topographic surface. Woods, screens of trees, hedges, or villages may modify considerably the visible and invisible areas, especially in country with little relief. After having constructed the theoretical boundaries, give attention (1) to screens, which in the visible areas may create additional dead angles; (2) in invisible areas to those objects (steeples, houses, woods) which may be visible above the protecting ridge because of their height. Observe also any defiladed roads likely to be revealed in the panorama by the tops of the trees along their sides. All these particulars should be carefully studied from the observation station.

By direct observation.—Having done this preliminary work on the map, proceed to the observation station and endeavor, by direct observation, to give more precision to the boundaries, the observations being based, as usual, on measurements of angles or bearings. Look for all prominent points which, by accurate location in direction alone, may serve to correct the positions of the boundaries—the disappearance of a ridge behind a nearer ridge, the intersection of a boundary with a line of the planimetric detail, such as a road or an edge of a wood, or with a line of the enemy's defensive works, such as a trench or a communication trench. Then study with field glasses, or with the observation telescope, every part of the ground seen between two successive boundaries. Note whether this ground forms a continuous slope or whether, on the contrary, it includes secondary ravines forming small defiladed zones that have escaped notice in the preliminary study of the map. Mark off the parts of the ground that are rendered invisible by natural or artificial masks, such as woods, hedges, villages, screens. Finally, in areas where the ground is invisible, look for tall objects which emerge above the ridge that masks them (summits of woods, tops of trees, roofs of houses, steeples). Identify them carefully and mark them on the map.

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It is only after having made this study completely and thoroughly that the observer can decide definitely on the visible and invisible areas.

The different zones should be distinguished by hachures or by conventional tints; for example:

1. Parts visible, no tint.
2. Parts defiladed by the form of the ground itself, flat black tint or heavy, close black hachures.
3. Parts situated on a visible slope but hidden by a mask, flat blue tint or black hachures more open and lighter than those of the defiladed zones.
4. Objects which are situated in a defiladed zone of the ground but whose tops are visible, in red.

ORIENTATION—ROUND OF THE HORIZON.

To orient oneself and to make what is called the round of the horizon at a point from which there are extensive views is to do what is needed to answer accurately the questions: Where are we? What do we see?

Use of plane table.—The best method of orientation involves the use of a plane table carrying a map on which the magnetic north is marked and of the leveling alidade or the clinometer rule. Occupy the station. If the plane table has the magnetic north marked on it, orient by compass and locate the position either by the three-point method on points of the general control or by a traverse connected with the surrounding planimetric detail. If the plane table has no magnetic north line marked on it orient roughly with the help of the approximately known declination, sight on a distant point to correct it, and then make a new location of the point. In any case, do not begin the round of the horizon until the location is exact, and especially until the orientation of the plane table has been completely corrected. Then by sighting with the alidade or with the clinometer rule all visible points can be identified with

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certainty. The evaluation of distances and the study of the forms of the ground on the map will generally be sufficient to remove any doubts that may arise. Pay particular attention to the visible and invisible areas and endeavor to identify the outstanding features of the landscape with the ridges indicated by the relief of the battle map. Gross errors will thus be avoided, such, for example, as thinking that one sees a trench that is indisputably located on a counter slope. If in doubt, construct a vertical section of the terrain.

Special problems.—It may happen that, in a particular direction, several ridges lie almost in line, one directly back of another, obscuring the recognition of details. In this case move the plane table to the right or left 100 or 200 meters. The angular deflections of the doubtful points will be sensibly modified, thus giving indications of their respective distances. If necessary, make a short computation of parallaxes.

For example, there are visible in almost the same direction a steeple A, unquestionably identified, and two intersections of trenches B and C, about the position of which there is doubt, for the battle map shows several ridges with fortified positions in the direction of A (see fig. 6). From the plane-table station measure the angular deflection between A and B. Ten mils is found, B being to the right. Go to the left 150 meters, measuring the distance by pacing. It is found that the angular deflection is increased and has become 35 mils, B being still to the right. The steeple A is recognized without doubt. It is 6,000 meters away. What is the distance to B?

The difference of the parallaxes α and β of A and B is equal to the difference in the angular deflections—

$$\beta-\alpha=35-10=25 \text{ mils.}$$

Now since the steeple A is 6,000 meters away, its parallax—

$$\alpha=\frac{150}{6,000}=25 \text{ mils.}$$

Therefore, $\beta=25+25=50$ mils. The parallax being 50 mils for 150 meters, the point B is about 3,000 meters away.

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If a similar computation gives the distance of C (not shown on the figure) as only 2,500 meters the uncertainty is removed and the points B and C are identified on the battle map.

Detailed observation of a restricted zone.—Plane-table reconnaissances are generally made with battle maps on a scale of 1:20,000. Nevertheless, for the detailed reconnaissance of a restricted zone—for example, the sector of a position assigned as target for destruction to a group of artillery—it is advantageous to use a map on a large scale (1:10,000 or 1:5,000). The entire map will not go on the plane table. Take only the necessary part of the map and place it on a celluloid protractor called a target protractor (see p. 226), which is set for direction and distance with the help of a prominent point in the zone to be studied, previously identified on the map on the scale of 1:20,000. Other observations will be referred to this prominent point by angular deflections taken with a field glass or with the monocular or binocular telescope.

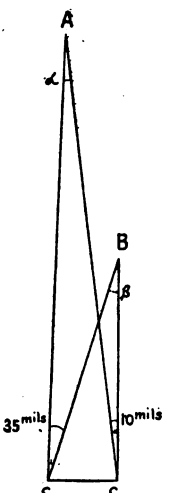

FIGURE 6.—Identifying objects by differences in parallax.

Orientation with instruments for measuring angles.—If the observer has no plane table or if he is in a place where he can not set one up—for example, in a trench—he can make the round of the horizon for the purpose of identifying objects by means of angles or bearings taken with another instrument, such as the compass goniometer, the periscopic goniometer, the binocular telescope, the monocular telescope, or the Peigné compass. The observed angles and bearings should then be plotted with the protractor on the map, which should be spread out as well as possible on a small table, a box, or the map stand. The impossibility of spreading out all that part of the battle map that is immediately needed will

generally lead to a division of the work into two operations. Pick out first a certain number of principal points of reference that may be easily identified, using the celluloid protractor and the map on a small scale (1:80,000 or 1:50,000), then study the details with the help of the target protractor and the battle map (scale 1:20,000, 1:10,000, and 1:5,000), of which only a part need be spread out at one time.

PANORAMIC SKETCHES.

ESSENTIAL FEATURES.

Panoramic sketches assume various forms, ranging from very complete and very detailed panoramas, executed at leisure, down to rudimentary perspective sketches made by the orientation officer during a rapid reconnaissance in order to indicate to his major the points of interest around the horizon. A panoramic sketch will not be really useful unless it fulfills the following conditions:

1. It must be simple and, leaving aside all esthetic considerations, indicate only what is essential—the ridges which separate foreground, middle distance, and background, prominent objects which may serve as reference points in the designation of details, and the principal points of the enemy's works identified on the map.

2. It must be accurate and should therefore be prepared on a definite scale. It must be controlled by measurements in azimuth and measurements of site. Graduations in azimuth and in site must be ruled upon it. Regard for accuracy requires the use of thin, well-defined, continuous lines and of clear, uniform tints, with none of the hazy outlines and half tints that constitute the charm of artistic landscape drawings.

3. It must be plain, plainer than the reality itself, and must bring out at first glance the details that are of interest to the artillerist, which have been discovered only after a patient ex-

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amination of the region—that is to say, it should bear conventional signs and annotation.

It is very evident that these conditions are not all combined in photographs. Nevertheless, photography may be used with advantage to facilitate the preparation of a panoramic sketch, as it furnishes at once a detailed framework supplementing that obtained by measurements of angles and of sites. The use of a photograph to supplement the control in the preparation of a panorama should always be preceded by a thorough and minute study of the region, made at the observation station with the help of the map and of optical instruments. It is only in this way that a judicious selection of details can be made from the photograph, so as to bring out those that will be needed and to eliminate those that would be useless, or even troublesome.

Having analyzed the ground that lies before us, we prepare a graphic record of the analysis, a record easily and rapidly made and useful to anyone who may later come to the same station. (See figs. 7–14, pp. 54–55.)

STUDY OF THE TERRAIN.

It is clearly necessary to begin by attentively studying the terrain, not only its visible but its invisible parts, by means of the map.

Having made a round of the horizon and thus identified objects that are clearly seen, endeavor to discover others by their direction and their location on the map. Determine exactly the directions of those that are not seen by means of the directions of those that are seen. Thus, for example, the map shows that between villages A and B there is a highway winding around the wood. Endeavor to discover with the field glasses where this road enters the villages A and B. Try to find it between the two villages. Perhaps certain parts at least can be thus

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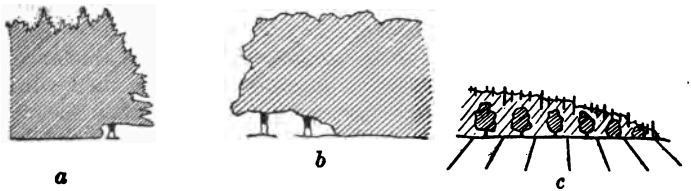

FIGURE 7.—Woods and vineyards in foreground. *a*, Fir woods; *b*, wood in full leaf; *c*, grapevines.

FIGURE 8.—Woods and vineyards in middle distance.

FIGURE 9.—Woods in background.

FIGURE 10.—Road through a village.

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FIGURE 11.—Village.

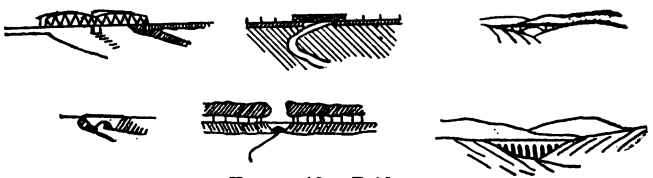

FIGURE 12.—Bridges.

FIGURE 13.—Trees, near and far.

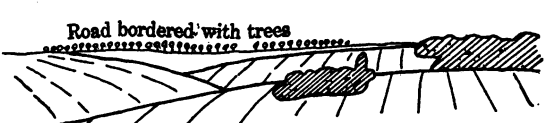

FIGURE 14.—Successive ridges.

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discovered. Perhaps none of it will be seen, but the edge of the wood which it skirts may be recognized. Again, between one ridge and another the map shows a valley. Endeavor to distinguish the two ridges one from the other, etc.

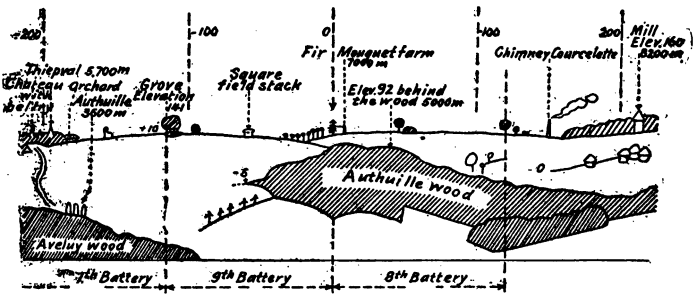

FIGURE 15.—Orientation officer's rapid sketch, with a few distances taken from the map and measured angles of site.

Having made this study, record it rapidly and in a way that shall be immediately comprehensible, in the form of a drawing, supplemented by annotations which do not overload it. The result thus obtained is called a panoramic sketch. It is not a copy of the ground; it is more—it is a caricature. (See fig. 15.)

DRAWING.

The principles of drawing to be applied are the following: Simplify the sketch by bringing out plainly the conspicuous or important points, so as to make easier the work of those (the commander of the battalion or the captain) who have to use it in artillery fire. Show on the sketch the angular deflections in mils, referred to a reference point near the center of the zone studied and also show the angles of site and the distances, measured on the map or measured with a telemeter, of the principal points in the region of the targets.

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As the sketch should be graduated horizontally and vertically, use cross-section paper if possible. Use a well-sharpened, fairly soft pencil that marks plainly.

Having chosen a reference point, first construct the skeleton of the sketch by locating certain objects; make the scale at least 5 centimeters for 100 mils. Place the reference point nearly in the middle of the sheet, locate prominent objects—steeples, conspicuous trees, and isolated houses. In height, start from the horizontal plane passing through the eye (the horizon line). In order to make plainer the distinction between successive ridges, the vertical scale may be exaggerated; it may be made double the horizontal scale. Both scales must be indicated. Having located certain well-defined points, complete the sketch by eye.

Ridges at different distances are indicated by lines of different weight; the nearer the ridge, the heavier the line. Highways or roads are shown by double lines; houses, settlements, and bridges by diagrams. Woods are indicated by simple outlines filled with cross hatching, closer or heavier for the nearer woods. Trees are represented by conventional signs resembling as much as possible the objects represented. The forms of the ground may be indicated lightly by hachures that follow the lines of greatest declivity or by contours. Anyone who can draw a little should be able to learn to prepare a clear panoramic sketch. Make no useless line on the sketch.

ANNOTATIONS.

The annotations should not obscure the drawing. They should therefore be kept separate and placed in the upper part of the drawing. They should be written horizontally on a line higher or lower, according as the object indicated is farther or nearer, in the order of the several distances represented. If necessary, use reference letters; also a few reference lines, lightly and clearly drawn, each ending in an arrow touching the object. Between the annotations showing what is visible, indicate the

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principal objects screened from sight, as shown by the map (villages, brooks, railroads). Do not forget to state precisely the point of view, which should be indicated below and to the left of the sketch.

The sketch should be made progressively. When a man begins he does not generally know how much time he has before him for the work. He will therefore indicate first of all the principal points of the whole sector. He can complete it later. The battalion commander, for example, on arriving at the position, need only take the sketch from the hands of the sketcher in order to understand the terrain before him.

It is desirable to apply distinctive names at once to those objects on the ground which may serve as reference points. It should be borne in mind that these names will be used later to designate these objects, and it may happen that the man who uses the names later—one, for example, with the infantry—may not occupy the same point of view.

GENERAL REMARKS.

In open warfare the only artillery sketch to be used is the rough panoramic sketch just described, which may be supplemented, if necessary, by small plan sketches. On the other hand, when warfare takes on its present form, it is possible to do more. At observation stations that are susceptible of a certain amount of permanent use or organization there is an advantage in preparing more elaborate detailed panoramic sketches on a large scale—10 centimeters for 100 mils or even more. Indicate on this large panorama all important details of the region, using, if necessary, powerful field glasses. Deflections and sites should be marked on the sketch.

It is well to reserve the top of the paper for annotations and the bottom for important data that may be used in executing artillery fire.

The panoramic sketch supplements very satisfactorily the battle map. It will be of particularly great service in training

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artillery observers, either noncommissioned officers or other intelligent men, who keep watch on the battle field. When a flash appears somewhere the observer refers it by eye to neighboring objects—for example, to the edge of the wood B between the third and fourth poplar (see fig. 16)—and marks its place on the panoramic sketch. The gun which has thus revealed itself will be located in direction, and, if the row of poplars and the wood B are sufficiently near together (see the battle map), an approximate idea of the distance can be obtained. This method of making a note on the sketch, with date and time, is the best and simplest method of recording the results of daily observations. It also enables anyone to keep track of new works prepared by the enemy, etc. The sketch should be kept constantly up to date. Finally, it has another tremendous advantage; in

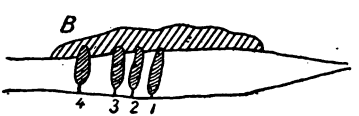

FIGURE 16.—Part of panoramic sketch.

case of relief, the new artillery will by this means inherit all the experience of its predecessor and can undertake its work without any period of transition or of feeling about.

It will be well for the battery commander to have at his observation station the panoramic sketches taken at auxiliary observation stations. He should endeavor to identify on the ground any objects shown on these sketches that are likely to be used as reference points by the auxiliary observers in fire for adjustment or in designating targets. For example, there are visible from an auxiliary observation station three trees A, which stand at the crossing of two roads (see fig. 17). From his own observation station the captain succeeds in identifying the three trees, of which he sees only the tops (see fig. 18). If a precise adjustment on the crossing of the roads has been

procured from the advanced observation station and the captain desires to renew his fire on that same target without being able to make use of his auxiliary observation station (as when communications are severed), he will have at least approximate control over his fire.

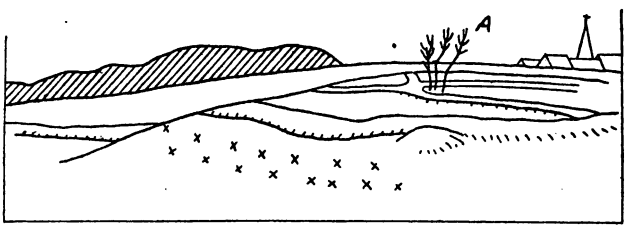

FIGURE 17.—Part of panoramic sketch showing trees at intersection of roads.

Of course the ground can be studied without the aid of neighboring observation stations. It will then be necessary for the captain to shift his position in order to see the aspect of the ground change. To keep the record of this changing aspect he

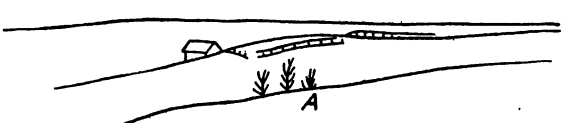

FIGURE 18.—Part of panoramic sketch made from principal post of observation, showing tops of trees at intersection of roads.

should preferably make small panoramic sketches from known points. (See figs. 19 and 20.) These will help him to interpret his large panoramic sketch. All such operations involve the application of the same principle.

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To summarize, under the conditions of warfare here considered the observer should neglect none of the means available for

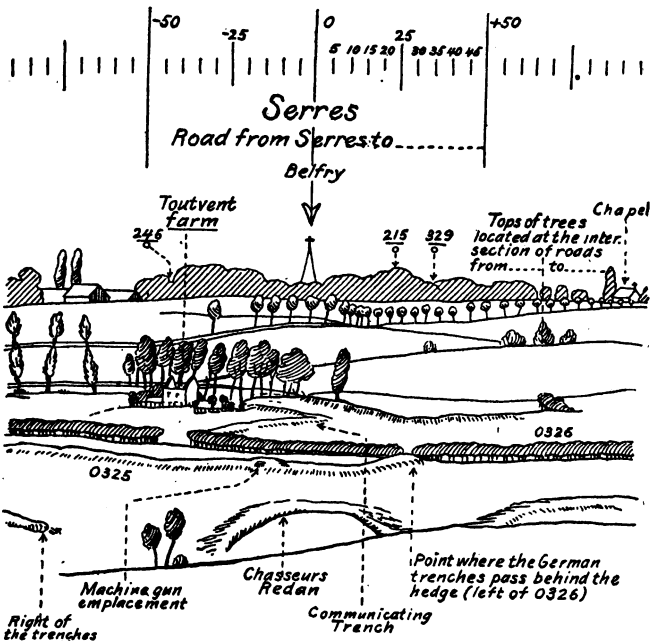

FIGURE 19.—Part of panoramic sketch made from the observation station of a battery. The figures placed at the objects are taken from the battle maps. A space is left beneath the sketch for instructions.

understanding the ground before him, in order that he may be able to direct fire with accuracy on a definite point not visible from the principal observation station.

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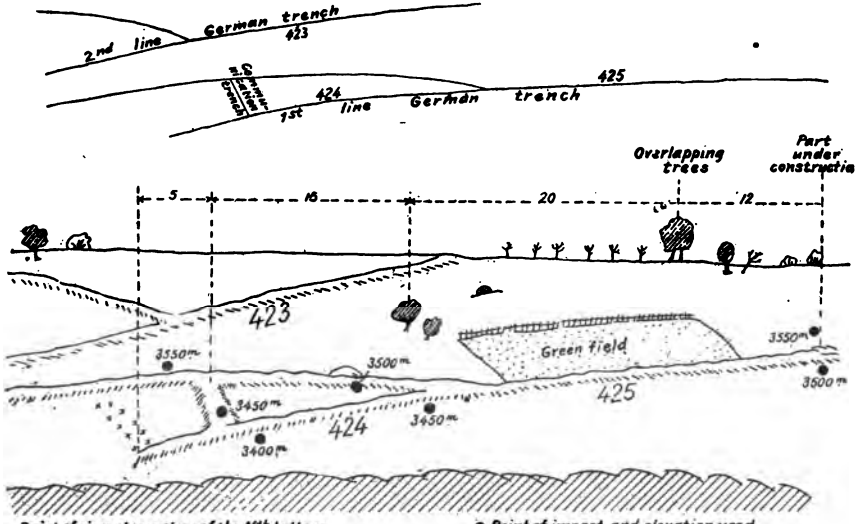

FIGURE 20.—Large-scale sketch made for detailed direction of fire on special targets. Numbers of trenches are taken from the battle map.

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TERRESTRIAL OBSERVATION BY BATTERIES AND BATTALIONS.[1]

SURVEILLANCE OF THE ZONE OF ACTION AND LOCATION OF NEW TARGETS.

PRECAUTIONS TO BE TAKEN.

To keep watch over the zone of action, to study the known targets, and to discover such as may reveal themselves, batteries and battalions establish on the ground an equipment for terrestrial observation, including regular observation stations, which are well equipped and insure permanent service, but including also more hastily organized observation stations, which are intended to supplement the regular ones; in other words, each unit has a principal observation station and several secondary ones.

Leaving aside the question of the material installation of the observation station, we shall confine ourselves to considering the organization of the observation service and the conditions which the observations must satisfy in order that they may afford all the accuracy and reliability that can be secured with the measuring instruments available.

The observation station should be located accurately by regular topographic methods, sometimes by geodetic methods. This work is done by the orientation officer of the battalion or the senior officer of the observation service to which the observation station belongs, or finally, if necessary, by the range triangulation detachments.

Every permanent observation service possesses one or more sighting instruments equipped for measuring angular deflections—sighting triangle, aiming circle, and monocular or binocular telescope. The principal instrument of the observation station should have a fixed orientation. This orientation should be known to all the authorities to whom the observer's reports are addressed. It may be defined in two ways:

[1] Observation of fire for adjustment is considered in Chapter VIII, pp. 187–193.

1. The observation station may have a principal reference point, a directrix, which corresponds to a reading of the instrument in round numbers—500 or 1,000. This reference point is a point of the general control, or, if that is lacking, a plainly identified point on the map. It is defined not only by its coordinates but also by the orientation of the line from the observation station to the reference point.

2. The orientation may be defined with reference to the Lambert system of squares, the reading 0 (zero) of the instrument corresponding to a sight along one of the axes of the system of squares. If this zero direction corresponds to the positive direction of *oy* in the Lambert system of squares and if the graduation of the instrument is clockwise the readings of the instrument give axial bearings directly. If the graduation is in the reverse direction, or if the zero does not correspond to the positive direction of *oy*, the readings bear a simple relation to the axial bearings. The instrument should be oriented by means of sights on one or more reference points. The bearings of these reference points are topographically determined at the same time as the coordinates of the observation station. The readings corresponding to these witness bearings are posted in the observation station and are a means of checking the stability of the instrument. They need not be known to the authorities who receive the reports, who must know only the geographic orientation of the zero, and, of course, the direction in which the instrument is graduated and the units of graduation—decigrads or mils.

When the observations have been thus accurately defined in direction, special precautions must be taken to locate them for range. The peculiarity of these observations, which are made by the sections for terrestrial observation, is that they are isolated, or, as they say, unilateral, as the reading of the instrument gives only one direction. For this reason the observation service of any one unit can obtain the exact position of new targets only under exceptional conditions. A target seen in a given direction may be located on the map with some

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certainty only if the observer is perfectly acquainted with his sector of observation—if he knows accurately what parts of the ground are visible and invisible and if he has identified all planimetric details and all visible targets. This reconnaissance work will require the use of the observation station board (battle map), the map of visible and invisible areas, and of panoramic sketches.

DOCUMENTS TO BE PREPARED.

Plotting board.—The observation station is equipped with a battle map fastened to a board. This battle map should have an orientation line corresponding to that of the instrument and that of the panorama. It should bear in addition all special annotations (letters, numbers, etc.) shown on the other documents. This simple precaution facilitates considerably the reconnaissance of the observation sector when the personnel is changed.

Map showing visible and invisible areas.—The zones that are visible and the zones that are invisible from the observation station should be accurately indicated, either on a special map posted in the observation station or on the plotting board itself. This very important document should always be prepared before the panoramic sketch.

Panoramic sketch.—It is indispensable to have at hand in the observation station an accurate and detailed panoramic sketch, bearing very numerous annotations (in the form of names, letters, and numbers), so as to permit an immediate comparison of the features represented with those shown on the maps.

Other documents.—Besides the above documents it is well to have at the observatory a battle map of the latest edition constantly kept up to date by the aid of the additions and revisions published by the range triangulation detachments or the topographic section. Finally, there should be posted at the ob-

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servation station a list of readings corresponding to the witness bearings of the principal instrument and the various special orders relating to the organization of the service—a schedule of work of the personnel, the duties of observers, and the nature and form of reports to be made.

Transmittal of observations.—The observations are transmitted either immediately over the telephone or periodically at a fixed time by telephone or in writing, according to the rôle of the observation station, but every observation should be immediately recorded in a notebook in definite form.

The notebook enables the observer to keep track of all his observations. It makes it easier for him and for the battery or battalion commander to understand each other, and in case of relief it is of considerable use to the new occupants of the observation station. The form and arrangement of the observations in the notebook will be prescribed by the orientation officer or by the chief of the service to which the observation station belongs and will conform to the following general rules: Every observation should include a statement of the time, of the direction, and of the supposed position of the object described, and finally of all military data regarding it that may be of interest to the authority to whom the observation is to be transmitted. Example:

At such an hour, minute, and (if necessary) second.

Such and such a reading of the instrument.

Such and such a target disclosing itself in such and such a way, being near such and such a point and changing its position in such and such a direction at such and such a velocity (if necessary).

Time and direction.—It is necessary that the timepiece of the observation station be regulated—that is to say, that it should be known how much it is fast or slow by the official time. There is only one official time, which is transmitted daily at 10.45 o'clock a. m. by the Eiffel tower and which can be received at all wireless stations. The comparison of watches from one man's hand to another's or over the telephone should be made not

approximately but by saying "top" precisely at an indicated second.

The direction may be given in the form, "to the right (or the left) of such a reference point, so many decigrads (or mils)," but it is better to ask the observer merely for the reading of the instrument, the zero of which always corresponds to a point well known to the battery or battalion commander.

STUDY OF THE MAP TO DETERMINE THE POSSIBILITIES OF BATTERY FIRE.

A study of the map of the ground near the targets will enable the observer to determine the conditions under which defiladed targets and those on counterslopes may be effectively reached. By extending this study to all the ground in front of the batteries the zones in the dead angles of fire of any given battery can be determined. These two problems are considered below.

Possibility and effectiveness of fire on counterslopes.—This study is purely topographic and its value depends upon the degree of accuracy of the battle map. In no case, however, should we neglect to make it, for we must ascertain as far as possible all the topographic conditions capable of affecting the precision of the fire. The question is particularly important for the fire of guns with a flat trajectory, and especially for the field artillery. The rule of counterslope enables us to solve, for the 75-millimeter guns, all problems concerning the effectiveness of fire on counterslopes and the determination of dead angles. Its use is explained in detail on the rule itself. There are also diagrams which enable us to solve the same problems.

In default of a rule or a diagram it is always easy, by computation or graphically, with the help of the map, to ascertain the conditions of the fall of projectiles on a counterslope.

Let us draw on the map the line of fire. Let d be the horizontal distance of two consecutive contours near the target measured in the direction of the line of fire and e the contour

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interval—commonly 5 meters on the battle maps. The slope of the ground in mils is $\frac{e \times 1{,}000}{d}$. Let s be the angle of site. The slope of the ground referred to the line of site (see fig. 21) is $p=i+s$. If, for this range, the angle of fall, c, given by the ballistic tables, is less than p, the counterslope is in a dead angle. If c is greater than p the counterslope can be reached, but the real angle of fall, with reference to the ground, is reduced to $c-p$. The probable error in range on the counterslope compared with the probable error from the range table is multiplied very nearly in the ratio $\frac{c}{c-p}$, or, more exactly, in the ratio $\frac{\sin c}{\sin (c-p)}$. The magnitude of this ratio gives an indication of the decrease in effectiveness that must be expected.

FIGURE 21.—Relation of angle of counterslope to angle of fall.

Determination of zones in dead angles of fire.—Dead angles of fire arise from—

1. The mask or protecting ridge behind which the battery is defiladed, which determines a minimum range short of which it is not possible to fire without striking the top of the mask.

2. The defilading of the targets themselves behind protecting ridges. The use of contour maps enables us to determine these zones in the dead angle with an accuracy which is in direct proportion to the accuracy of the contouring.

Determination of the minimum range.—From the gun emplacement itself in several specified directions the angle of site of the mask is measured. The minimum range is required for each of these directions. If the mask is some distance from the gun it is necessary to allow for the drop in the trajectory. The minimum

elevation of the gun is obtained by adding to the measured angle of site the angle of elevation corresponding to the distance to the mask.

Example: 75-millimeter gun; explosive shells. The mask is 500 meters away and its measured angle of site at the gun is 50 mils. For 500 meters the angle of elevation is 8 mils. The minimum elevation to be given to the gun is 50+8=58 mils.

The minimum elevation converted into range by aid of the ballistic tables gives a first approximation, which in rough country may be very inexact. To get an accurate minimum range, allowance must be made for the altitude of the point of fall, and it is here that the map comes in. Therefore we take from the map (1) the altitude of the gun and (2) the altitude of the point of ground corresponding to the first approximation found for the minimum elevation. From these we deduce the angle of site. By correcting the first minimum elevation for this site we obtain a second approximation. We can then calculate the angle of site of the second point obtained and make, if necessary, a third approximation.

Example: 75-millimeter gun; explosive shell. The altitude of the gun is 290 meters. The possible minimum elevation is 58 mils. An angle of elevation of 58 mils corresponds to a range of 2,300 meters. The altitude of the ground at a range of 2,300 meters in the direction considered is 232 meters. The angle of site is—

$$\frac{232-290}{2.3}=\frac{-58}{2.3}=-25 \text{ mils.}$$

This ground can not be hit, for it would be necessary to give the gun a total elevation of 58—25. Let us increase the angle of elevation by 25 mils: 58+25=83 mils. The corresponding range is 2,940 meters. The map shows the altitude of the point at 2,940 meters to be 207 meters. Angle of site:

$$\frac{207-290}{2.94}=\frac{-83}{2.94}=-28 \text{ mils.}$$

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The second approximation is still insufficient. The quadrant elevation to be given to the gun would be, in fact—

	Mils.
Elevation	83
Site	−28
Quadrant elevation	55

Not less than 58 mils can be used. We are still striking 3 mils below the top of the mask. The variation in range corresponding to 3 mils is 60 meters. Let us try 3,000 meters. The altitude is 210 meters; the site is—

$$\frac{210-290}{3}=\frac{-80}{3}=-27 \text{ mils.}$$

	Mils.
Elevation	86
Site	−27
Quadrant elevation	59

This clears the crest by 1 mil. The minimum range in the direction considered is 3,000 meters, instead of the 2,300 meters that would have been obtained if the form of the ground in the vicinity of the point of fall had not been considered.

Dead angles created by the form of the ground in the vicinity of the targets.—Every point on a counterslope for which the declivity, measured in the direction of fire, is greater than the angle of fall is defiladed from the fire. A rapid examination of the battle map, accompanied by a few measurements of slopes, will show the areas to which this may apply. In these areas the limits of the zones in the dead angles may be defined by determining the points of contact of the grazing trajectories and their points of fall.

For the 75-millimeter gun this construction can be made with the aid of diagrams prepared especially for the purpose and accompanied by all explanations needed for their use. In default of a special diagram a problem can be solved by graphic construction on the map. The ballistic data (angles of fall)

are furnished by the range tables, or, for the 75-millimeter gun, by the counterslope rule.

The construction consists in making profiles of the ground along vertical planes radiating from the position of the battery. Such profiles need not be made, of course, except for areas with slopes greater than the angles of fall.

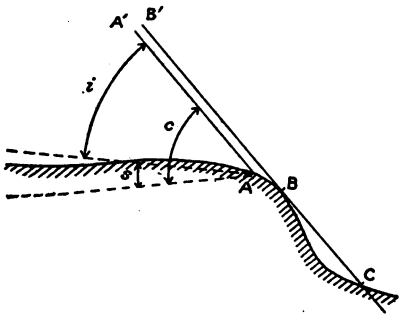

FIGURE 22.—Profile showing method of determining point of tangency on counterslope in dead angle.

Let ABC in figure 22 be one of these profiles. Through the point A, chosen by inspection in the neighborhood of the point of tangency that is sought, draw the tangent AA′ to the trajectory defined by its inclination to the horizontal. If c is the tabular angle of fall and s (with the proper sign) the angle of site of the point A, the inclination (i) of the trajectory is $i=c-s$.

The straight line B′BC parallel to A′A and tangent to the profile at B gives the point of tangency B and the point of fall C of that trajectory. The space BC is in the dead angle.

If the slopes and the angles of fall are small it is well to increase the vertical scale of the profile. In this case the angles of fall are to be plotted not with a protractor but by their tangents expressed in mils.

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Example: 75-millimeter gun; explosive shells. Range is 3,000 meters. (See fig. 23.)

	Mils.
Angle of fall (c)	133
Angle of site (s)	16
Inclination of the trajectory (i)	117

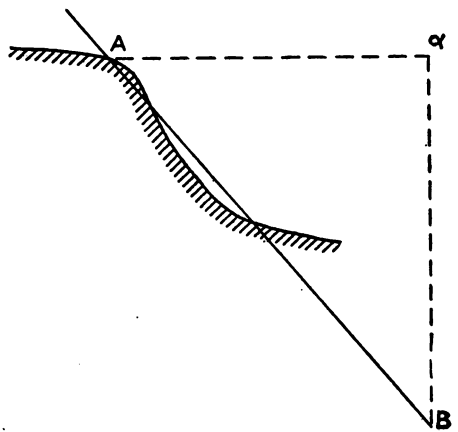

FIGURE 23.—Example of diagram with increased vertical scale.

The profile has been constructed from the map on the scale of 1:20,000, and the vertical scale has been magnified 10 times. In a horizontal direction take—

$A\alpha$=1,000 meters=50 millimeters (scale of 1:20,000).

Take vertically—

αB=117 meters=58.5 millimeters (scale of 1:2,000).

AB is the tangent to the trajectory at the point A.

This substitution of the trigonometric tangent for the angle itself, although legitimate for small angles, ceases to be so for angles greater than 350 mils. For greater angles of fall—that

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is, with the 75-millimeter gun, with ranges exceeding 5,000 meters—the profiles of the ground should be constructed in their actual form without vertical exaggeration, and the angles of fall should be plotted with a protractor.

STUDY OF TARGETS FROM AERIAL PHOTOGRAPHS.[1]

GENERAL FEATURES.

Aerial observation is the only means of reconnoitering targets that are defiladed from terrestrial observation. In connection with photography it constitutes the most complete and most accurate method of investigating the enemy's works, even in their visible areas. Photography is the only method which, whether combined or not with direct observation, enables one to make an exact representation of the whole of these works. It is the only means of reconnaissance which finds expression in impersonal testimony—the photographic proof—verifiable by everyone.

Orientation officers will almost never have to concern themselves with the geometric work of making plan projections from photographs taken from airplanes. The work of plotting the results on the battle map is done by the range triangulation detachments, by the topographic sections of the army corps, and by the divisional topographic sections. On the other hand, the orientation officers will often need to study the photographs in order to interpret their details from a tactician's point of view. This examination of photographs forms a very important part of the reconnaissance of targets. The results of this study should be coordinated with the results of direct observation. Details that by themselves mean nothing on a photograph will gain significance when compared with notes made at an observation station or with oral information furnished by an aviator or an infantry observer.

[1] Notes on the interpretation of aerial photographs, December, 1916 [Notes sur l'interprétation des photographies aériennes].

It is well to compare photographs of different dates. Sometimes an aerial photograph enables one to obtain, at the moment of their construction, details of the enemy's works that will be effaced later, such as covered trenches, interior arrangement of a shelter, or excavation at a saphead. In order to investigate properly the character of such details it is important to ascertain the direction from which the photograph was taken. A very satisfactory clue may be obtained from the appearance of houses, of which either the roof only, a gable, or a façade is visible, according to the position of the airplane. We may also make use of the appearance of the edges of woods and of trees along roads, etc. If the photograph has been taken in sunny weather we should notice the direction of illumination in order to be able to interpret the shadows cast. By paying attention to the direction in which the photograph was taken and to the shadows cast, we often succeed in getting hold of details which would otherwise escape us—the outline of a parapet, and sometimes, with very good photographs, the approximate profile of a trench.

The stereoscopic study of photographs is to be recommended whenever we can get negatives taken during the same flight at nearly the same altitude and partly overlapping. We must not forget that the tactical interpretation of the details of photographs is very difficult. We may sometimes attain absolute certainty, but more frequently we can get only more or less plausible indications, which serve to verify and to reinforce indications from other sources.

The principal points with which the study of photographs deals are indicated below.

STUDY OF TRENCHES.

Study the peculiarities of the trace of trenches; note the elements of the trench that are constructed for flanking, where machine guns should more especially be looked for; note the density and the form of the splinter proofs—whether indented or semicircular. Some splinter proofs are double and form a

complete circle, visible only at the time of construction, one-half open above ground, the other half covered. This arrangement, which facilitates circulation and permits the multiplication of shelters, indicates a trench intended to be occupied strongly.

Profile.—The profile is not discernible except on photographs taken with long-focus apparatus. Shadows may give a hint. Sometimes the firing banquettes and the exit ladders [for going over the top to make an attack] can be seen. The lengths of these ladders and the amount of earth excavated may give an idea of the depth of the trench.

Loopholes.—In the older works loopholes were often visible in comb trenches. The Germans seem to have completely abandoned the use of loopholes.

Tactical rôle of trenches.—Distinguish between combat trenches and parallel or communication trenches. The study of peculiarities of trace and of profile will bring out the indications which the topographic situation affords on this point. Covered communication trenches are recognizable by their ventilating chimneys (lines of black points).

Shelters.—Covered shelters are clearly visible. Try to distinguish them according to their purpose—shelters for men, command posts, dressing stations, ammunition shelters, machine-gun shelters. This study is generally very difficult but is sometimes possible at the time of construction, as the shelters are then not yet covered over and their dimensions and form can be estimated.

Cave shelters, though much less visible, may be discovered by their entrances, their ventilating chimneys, and excavated matter.

The number of shelters gives some indication of the garrison intended for the trench. During the preparation for attack shelters are multiplied and sometimes constitute important places of arms.

Machine guns.—Machine guns are likely to be placed either in flanking positions or in a straight trench opposite a reentrant

angle of the entanglement in which the assailants instinctively collect. They are frequently under shelter, the shelter being under the parapet, either in front (communication trench, covered or uncovered) or behind the trench (shelter raised above its surroundings). Note the shadows cast. The guns are sometimes in a trench, open to the sky. The signs which suggest a machine gun are—greater definiteness of the parapet, ground cleared for the field of fire, communication trench in front (listening post or observation station), communication trench behind (shelter from bombardment for the machine gunners).

Mine throwers.—Mine throwers may be found in open square pits. Endeavor to distinguish such pits from latrines and cesspools. The pit for the mine thrower is larger and more distinct and is connected with the trench by a rather long and crooked passage. The pits may be in recesses in the parapet where the niches for ammunitions are visible. Some emplacements for fire are covered; they can then be recognized only by their rectangular embrasures. Mine throwers are often grouped in batteries of two, three, or four.

Accessory defenses.—The wire entanglements are very often visible as narrow gray bands, sometimes marked by dots (posts) when photographs are excellent. Estimate the width of the entanglement and look for the breaks in it (trails). Abattis show as conspicuous black lines. Military pits are very conspicuous.

Listening posts.—Connected with the main trench by a trail or a long communication trench, which often traverses the entanglement. The path taken in going the rounds to inspect the night sentries is often visible.

Sapheads.—Disclosed by the excavations. Watch excavations of short communication trenches in front of the first-line trenches.

Closed works.—Locate and count the shelters. Look for emplacements for machine guns.

Villages included in a line of trenches.—Look for approach trenches to cellars serving as shelters from bombardment. Also

look for shelters outside of houses, for barricades, fortified houses and inclosures.

Cantonments.—Look for signs which may give information about the strength of the effectives in barracks and about the most frequented points of assembly or passage—groups of huts, parks, watering troughs, temporary bridges, frequency of movement, tracks of wagons, of pedestrians, and of horses.

STUDY OF BATTERIES.

The detailed study of the enemy batteries from aerial photographs may furnish very useful information concerning the organization of the battery, number of guns, front occupied, location of shelters, ammunition dumps, cartridge magazines (generally some distance from the battery, with which they are connected by a trail or communication trench), and direction of fire (which may be oblique to the front of the battery and is indicated by the orientation of the emplacements, cells, or casemates).

Method of protecting the guns.—Batteries protected by breastworks, sunken batteries, casemated batteries.

Distinction between active batteries, emplacements of reinforcing batteries not occupied, abandoned emplacements, false batteries.—Photography by itself rarely enables us to make these distinctions to a certainty, but it often furnishes signs that confirm the information given by direct observation, either terrestrial or aerial, or by plotting from gun flashes or from sound. The signs of activity which may be visible on photographs are tracks left by the personnel serving the guns, the blast of the guns (marks on the ground, which sometimes, for batteries at the edge of a wood, take the form of little notches in the edge). The supply trails for active batteries are hidden and run the length of the emplacement. They are either nonexistent or are very evident (converging roads) when it is a false battery.

Artillery commands.—The study of trails and of telephone lines must be relied on primarily. Telephone lines are often

visible. Lines in a conduit show as narrow, straight ditches; aerial lines fastened to posts show as whitish, equidistant points in a straight line; the posts themselves or their shadows are visible on long-focus photographs taken in clear weather.

Observation of the fire of our artillery.—Aerial photographs taken during artillery preparation enable the observers to make a systematic study of the results of our fire. They also enable them to recognize the errors in the adjustment of the fire.

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CHAPTER IV.

PREPARATION FOR FIRE; TOPOGRAPHIC OPERATIONS.

DETERMINATION OF THE INITIAL FIRING DATA.

It is absolutely necessary that the technical preparation for fire be made with great care if an accurate fire is to be opened rapidly without frittering away ammunition uselessly. Lack of sufficient preparation renders adjustment slow and difficult and may even make it impossible. An error of as much as 100 mils in the deflection is not at all impossible if the preparation for fire has been made awkwardly or carelessly, so that at 5,000 meters the rounds will fall at least 500 meters from the point at which the observer expects to see them fall.

In battle, especially when batteries are numerous and active, a poor preparation for fire may prevent an observer in an airplane from spotting the fire he is to observe. It may then happen that a unit which for several months has secured excellent adjustment by airplane can no longer obtain a single hit, because it has made a forward movement which has caused it to lose touch with the terrain and with the points of reference for its habitual targets. At this moment, usually, the enemy is executing numerous movements and his batteries are unprotected. This condition may last up to the time when adjustment by direct observation reestablishes the proper aiming of the guns. The points of reference by which the fire is adjusted then permit the transfer of the fire by means of the topographic or battle maps, which may again be used under suitable conditions. But all this has required time, and excellent opportunities for effective action have been lost. The use of the guns alone has solved much too slowly a problem that could have been solved in a few moments by some simple topographic measurements.

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DETERMINATION OF THE POSITION AND ALTITUDE OF THE DIRECTING GUN.

MODE OF OPERATION.

The initial firing data are the direction, the range, and the angle of site, or the direction and the quadrant angle of elevation combining the range and site. To determine the range and site, the coordinates and the altitude of the target being known, we must determine the position of the directing gun—its coordinates and its altitude. To make sure of the direction of the directing gun it is enough to know the exact direction of the aiming line to which are referred the deflections laid off on the aiming circle. The direction of the gun will then be known for any given division of its aiming gear.

At first sight these two questions (the determination of the position of the directing gun and of the aiming line) seem directly connected, for if the position of the directing gun and that of some reference point visible from its aiming circle are known, the aiming line also is determined. But it must be noted that it is not possible in practice to derive an azimuth from even fairly accurate coordinates of two points if these points are relatively close together. By so doing we may get errors that are absolutely inadmissible. For example, if the gun and the aiming point are 400 meters apart, and if there is an error of 20 meters in the map position of each point perpendicular to the line joining them and in opposite directions, the error of the resulting azimuth is $\frac{40\times1,000}{400}=100$ mils. Fundamentally, therefore, two separate operations will almost always be required to determine the position of the directing gun and the origin of deflections or aiming line used in aiming the directing gun. And of these two independent operations—the location of the directing gun and the determination of the aiming line—the second must be considered the more important, because an error in it will result in deflecting

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the plane of fire and displacing the point of fall by an amount proportional to the range.

In doing topographic work the orientation officers or the battery officers use a board covered with a sheet of white cross-section paper or a battle map. This will here be called simply the plane table.

In batteries, on the other hand, the firing data are obtained from a map or a sheet of white cross-section paper, fastened to a board, to which have been transferred the aiming line and the position of the directing gun, the targets, the reference targets, and the observation stations. This is the plotting board.

The plane table is used for current surveys only. The lines on it may be rubbed out when the results have been obtained and entered in a notebook. The plotting board, on the contrary, is designed for permanent use. The annotations and constructions drawn on it by the orientation officer should be preserved and handed over to his successor when he is relieved, if they are likely to be useful.

DETERMINATION OF THE POSITION OF THE DIRECTING GUN FROM POINTS OF THE GENERAL CONTROL.

Locations made with the aid of points of the general control involve merely applications of well-known topographic methods. The choice of methods—three-point, intersection, direction and distance, traverse, or their combination—should be governed, first, by the desire to avoid cumulative errors and consequently to confine the surveys to the smallest possible field by tying them to the nearest possible control points; second, by the constant desire to provide indispensable checks—at least one.

As the directing guns occupy defiladed positions it will often be impossible to determine their positions directly from points of the general control, either by the three-point method, by intersection, or by resection. It will generally be necessary to resort to a traverse. This traverse will start either from a

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control point or from a point determined by the three-point or intersection methods. There must always be a check. The survey will close on similar points.

It is necessary, first of all, with the aid of a battle map or the regular topographic map, to make a reconnaissance to determine exactly what surveys are to be made. In topographic work as well as in military operations it is necessary, first, to know what is wanted—that is to say, what is most advisable. The method to be used then readily suggests itself. The measurements should be as few as possible. Excessively long traverses and also distant intersections are to be avoided. Below are some examples:

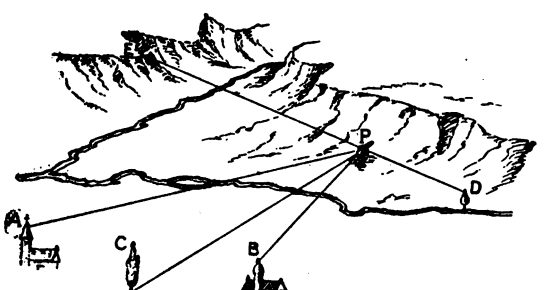

FIGURE 24.—Determination of position of gun by three-point method.

Example 1, three-point method.—The gun P is set up at the edge of a very wide valley (fig. 24). In this valley there are visible numerous control points—steeples A and B, poplar C, fir tree D, apple tree E (on a spur). At P make a three-point location with the best instruments at hand. The operation will take several minutes and will give, if well done, an accurate result. There will be no accumulated errors.

Example 2, intersection and resection.—Behind the directing gun there are seen, in a rather wide valley (fig. 25), three control points—at A a wayside cross, at B an elm, at C a shack. There is at hand for the survey only an instrument with-

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out a compass needle (a plane table, goniometer, or theodolite). The simplest and quickest method is, again, the three-point method; but examination of the map reveals that the gun and the points A, B, and C are all very nearly on the same circle.

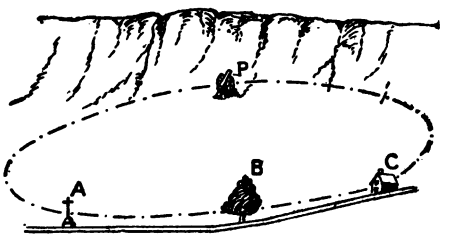

FIGURE 25.—Example in which the only three control points visible lie nearly on the same circle; three-point method not available.

The three-point method must be abandoned, and intersections must be made from the three points A, B, and C, each of which must be occupied. If the points B and C for any reason can not be occupied, the point P may be determined by resection on B and C after the line AP has been drawn on the plane table.

Example 3, traverse tied to three-point locations or to intersected points.—From the position of the battery no known point can be seen, but from the masking ridge a number of points

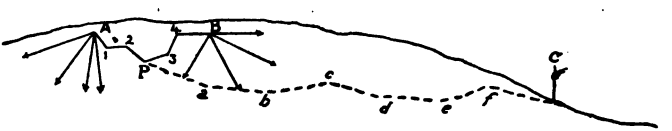

FIGURE 26.—Determination of position of gun by traverse between three-point locations.

are visible whose coordinates are exactly known. Two points, A and B (fig. 26), both defiladed from the enemy, and both affording good three-point locations, are selected. The position

of the gun is then determined by a traverse, starting from A, passing through P, and closing on B. The error of closure is adjusted.

Instead of determining B, we might have replaced the traverse P 3 4 B by the traverse P *a b c d e f* C, ending at the telegraph pole C, which is a control point. If the traverse P C is much longer than the traverse P B we would not only lose in accuracy but would also have done a needless amount of work. If, on the contrary, B and C were only 100 meters or so apart, C could be substituted for B. The two points A and B, or one of them, may, if necessary, be located by intersection.

Example 4, intersection from two three-point locations or from two intersected points.—The gun P (fig. 27) is on a gentle slope. The entire slope is visible from the gun, but no control points are visible. As in example 3, it has been possible to

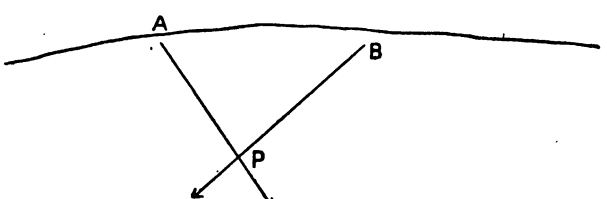

FIGURE 27.—Determination of position of gun by intersection from two three-point locations.

locate two points A and B by the three-point method. From A and B the gun can be seen. Its position therefore can be determined by two sights on its aiming circle, or goniometer. To provide a check the angle APB is measured with the aiming circle. The sum of the three angles A+B+P should be equal to 3,200 mils, if the graduations are in mils.

Example 5, traverse tied to the general control.—In wooded country or in work done at night traversing is the only practicable method. Start from any control point and, passing through the gun, close on a second control point; adjust the

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error of closure. Select such control points as will expedite the work. The shortest traverse, however, is not necessarily the quickest.

DETERMINATION OF THE POSITION OF THE DIRECTING GUN BY MEANS OF THE PLANIMETRIC DETAIL OF THE TOPOGRAPHIC MAP OR THE BATTLE MAP.

METHODS OF PROCEDURE.

The position of a gun may be determined by the aid of a map by reference to the planimetric details, these details having been duly verified. It is not enough merely to read the map with care. Instruments and topographic methods must be employed in order that the map may be used with certainty and precision. First of all, the details of the topographic maps or of battle maps must be verified. Make sure that the details have been correctly identified and that no gross error has been made, such as taking one road for another or the edge of a wood for a former edge, now vanished. Check the accuracy of the topographic map or battle map and ascertain whether there have not been modifications since its issue. For this purpose occupy one or two points with plane table and compass and compare the direction and distance of the neighboring details on the ground with those on the topographic map or battle map. Make a traverse through the points to be verified. These checks should include three or four points. Having made these preliminary determinations, connect the position of the gun with at least two points of detail suitably checked. The principal methods are:

1. Traverse: Start from one of the known points, pass through the directing gun, and close on another point.

2. Three-point method: Occupy a station as near as possible to the gun, where a three-point location can be made by sighting on at least three or four points of detail. From this station the position of the gun is determined by measuring direction and distance (polar coordinates).

3. Intersection: From three identified points take three sights on the gun; two will suffice if one distance has been measured.

All combinations of these methods are good.

METHODS OF PROCEDURE WITH THE BATTLE MAP ON THE SCALE OF 1: 20,000.

First method: The points needed are transferred to a plane-table sheet from the battle map by their coordinates, which are measured within one-tenth of a millimeter with a double decimeter scale. It is best to do the field work on a scale of 1: 2,000, of 1: 5,000, or of 1: 10,000. The accuracy of the starting points is not in this way increased, as they are taken from a battle map on a scale of 1: 20,000, but the graphic errors in the survey itself are reduced. This is especially desirable when the traverse is somewhat long. Furthermore, in addition to the plot made on the scale of say 1: 2,000, another plot should be made on a scale of 1: 20,000, which will disclose the errors that might otherwise be made in taking sights on the more distant points.

Second method: The battle map is fixed on the plane table by thumb tacks or pasted on the edges. If two sheets are required, paste them edge to edge, making sure that the kilometers of the squares spanning the line of junction actually preserve their proper lengths. The direct use of the battle map permits more rapid work because it avoids the previous transfer of points, but it necessitates working on the scale of the battle map used.

Third method: Measurements may have to be made with some other instrument in the absence of a plane table. Any instrument may be employed—theodolite, tachymeter, binocular telescope, monocular telescope, artillery compass goniometer, telemeter, or tape. Distances may be measured even by pacing. All measurements made are carefully entered in a pocket notebook, and the entry is accompanied by an explanatory sketch showing the scheme of the survey. The plotting is then done on the battle map or on tracing paper.

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These different methods involve laborious plotting, which is avoided by plane-table methods. Such plotting is always liable to error. Nor should such makeshift methods be used except when no plane table is available, when bad weather makes its use impossible, or when the operation is so simple that the data can be plotted directly on the battle map with a scale and a protractor.

RELATIVE ADVANTAGES OF THE USE OF THE GENERAL CONTROL AND OF THE BATTLE MAP.

As a rule the points of the general control should be used to determine the position of the directing gun. The battle map may be used to get a first approximate position, with a view to avoiding gross errors, but it should not be used for any other purpose if it is of doubtful accuracy, as it may be if it is not based on regular surveys and if its planimetric detail has not been checked by the range triangulation detachments. But it should be noted, on the other hand, that surveys starting from points of the general control are usually more troublesome and, above all, longer than surveys based on the battle map. Locations made with the aid of the numerous details of a well-made battle map may be more accurate than those based on sparse triangulation control, because the accumulation of errors is avoided.

DETERMINATION OF THE ALTITUDE OF THE DIRECTING GUN.

The altitude can as a rule be taken from the battle map or the regular map, but it may be necessary to determine it instrumentally if interpolation between the contour lines of the map is uncertain by reason of the character of the terrain, as, for example, in maps of a very rough country, where the contours are close and it may be supposed that they are not exactly in the right places. Therefore, whenever there is time, the orientation officer should determine instrumentally the altitude of the directing gun. If he has a battle map on which the con-

tours are simply enlarged from those on a map on the scale of 1:40,000, he can, after a few measurements, gain an idea of the relative value of the location of the planimetric detail and of the representation of the relief of the region.

DETERMINATION OF THE AIMING LINE OF A BATTERY.

GENERAL CONSIDERATIONS.

The fire of a battery is usually directed by the aid of one of the guns, generally by the right-hand one, the other guns being

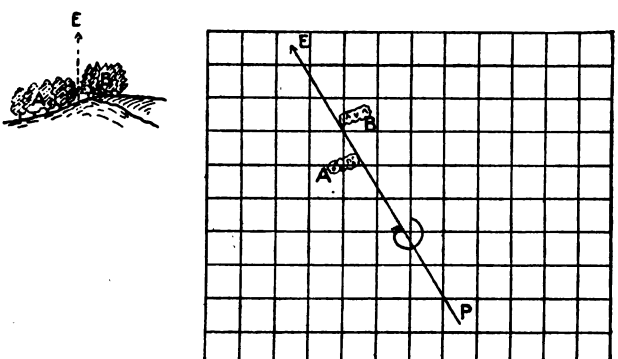

FIGURE 28.—Example of a fictitious aiming point consisting of the intersection of the outlines of two distant woods.

then directed by forming a sheaf of trajectories. Here we shall consider only the determination of the direction of the gun called the directing gun (field artillery) or guiding gun (heavy artillery), the formation of the sheaf of trajectories being an everyday operation described in the artillery regulations. It should be noted, nevertheless, that some of the topographic methods given below are directly applicable to the forming of the sheaf of trajectories.

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In aiming the directing gun use is made generally of what is called an aiming line. The aiming line is a line that is clearly defined by actual objects on the ground, and whose direction has been accurately determined. The objects which define it are, first, the aiming circle of the gun (or the mark that replaces it), and, second, an aiming point consisting of some natural object (tree, shrub, spot of bare ground), an artificial object (steeple, chimney), a stake or mark specially placed for the purpose, or even a fictitious point that appears real to an observer at the gun. For example, the aiming line for a gun P (fig. 28) may be defined by the notch E formed by the intersection of the two apparent outlines of two pieces of woodland A and B, several kilometers apart. The line PE is perfectly definite on the ground, but the point E does not really exist.

To determine the aiming line we must make topographic surveys that will permit it to be drawn accurately on the plane table, on the battle map, or on the topographic map. As has already been stated, the location of the directing gun and of the aiming line are almost always determined by independent surveys. However, the coordinates of the directing gun may be used in connection with those of a topographic aiming point to define the aiming line when the point is very distant and its position is accurately known.

On the other hand, it may happen that in certain positions of a battery and under certain particular conditions no recourse can be had to an aiming line to aim the directing gun by the aiming circle, and it becomes necessary to aim it directly by topographic methods. The three operations to be considered are, in short, the following:

1. Direct determination of the azimuth of the aiming line.
2. Determination of the aiming line by the coordinates of an aiming point.
3. Direct aiming of the directing piece by topographic methods and without the use of an aiming line.

In the foregoing there has been no mention of the *direction of surveillance.* The direction of surveillance is, in fact, en-

tirely different from the aiming line. It is the direction of a particular point in the enemy zone, chosen usually in the middle of the zone of normal action of the battery. It is rarely defined by actual objects on the ground, but only by a certain graduation of the aiming circle, which results, however, from a previous determination of the aiming line. There may be several directions of surveillance for a battery. When the aiming line has been determined topographically, a simple measurement on the map gives the angle which the direction of surveillance makes with it—a fact which makes it possible, if desired, to define the direction of surveillance on the ground by means of a stake in front of the directing gun, an operation which is sometimes required of orientation officers.

On the other hand, the point which defines the aiming line on the ground should not be confused with the auxiliary aiming points, natural or artificial, used by the gunners and chosen by them in aiming for practical reasons and under the military exigencies indicated in the regulations.

DIRECT DETERMINATION OF THE AIMING LINE.

The topographic surveys may be made either by plane table or by instruments for measuring angles. Astronomic methods may also be used.

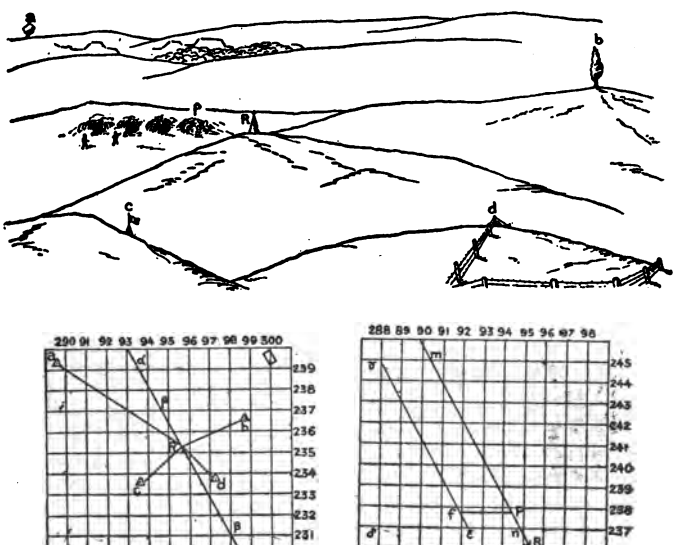
TOPOGRAPHIC METHODS.

USE OF THE PLANE TABLE.

First method: The directing gun is visible from a point which can be determined by the three-point method—that is, from a known point from which is visible another distant known point. Such a point is chosen as aiming point to define the aiming line—a condition shown in figure 29. The point is a boundary monument R, from which are visible in the direction of the enemy only the top of a solitary tree a and toward

the rear a steeple *c*, a tree *b*, and a fence post *d*. The coordinates of these four points, *a*, *b*, *c*, *d*, appear on the list of the coordinates of the general control.

To facilitate the work a small mark is placed on the goniometer of the directing gun. Occupy R, center over it, then



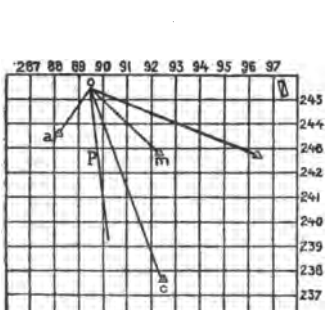
Plane table. Plotting board.

FIGURE 29.—Determination of aiming line.

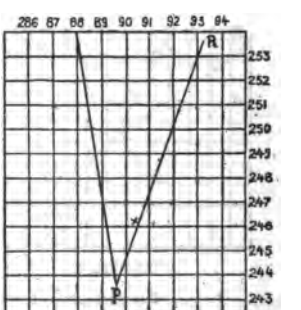
orient the plane table on the most distant of the visible points, *a*. Sight on the mark *p*, draw the line R*p* for the entire length of the rule of the instrument, and prolong it across the whole board with an accurate straightedge.

It only remains to transfer this line to the plotting board, which consists, for example, of a fragment of the battle map

on the scale of 1:20,000, pasted by its edges to the board. Choose two points α and β near the edges of the plane table that are parallel to the abscissas of the system of spaces. The ordi-



Plane table.



Plotting board.

FIGURE 30.—Determination of aiming line from a station from which the aiming point is invisible.

nates of these points are respectively 239 and 231. On the plotting board we take two points [γ and ϵ] having the same abscissas (x=288) and having ordinates differing by 8 kilo-

meters (239—231). Take δe=difference of the abscissas of α and β=(−293.610+298.000)=4.390. γe is parallel to the aiming line. Lay off $\gamma m = fP = en$. The straight line mPn is the aiming line. It is possible that the aiming point itself may not appear on the plotting board, but this is of no consequence.

Second method: From a point either known or easy to locate the directing gun is visible but not the aiming point chosen by the battery. From O (fig. 30), situated in a trench leading to the observation station, the directing gun is visible; also the following known points: A tree a, a windmill m, a fir tree q, and a steeple c, far distant toward the rear. From the battery established on a counterslope these different points can not be seen, but from the directing gun a wayside cross R is visible, which is chosen as aiming point. From O this wayside cross is masked by a wood.

Occupy the point O and locate it by the three-point method. It will be available also for determinations relative to the observation station. Orient the plane table, using the distant steeple c, sight on the directing gun P, drawing the line OP along the entire length of the straightedge. Transfer this line to the plotting board, either in the way indicated in the description of the first method or by making use of the squares. Either of these operations affords a check on the other. With the goniometer or with any other instrument measure the angle OPR, and plot by protractor the line PR on the plotting board. Locate on this aiming line the aiming point R, using, if necessary, the distance PR.

In figures 29 and 30 the difference in the arrangement of the two boards will be noted. It is assumed that the mean direction of fire was toward the north. The point P has been located on the battle map on the scale of 1:20,000 (which has been cut up for this purpose) toward the bottom of the plotting board. On the plane table, on the other hand, the points have been placed with the sole view of facilitating the survey work, and P is near the top.

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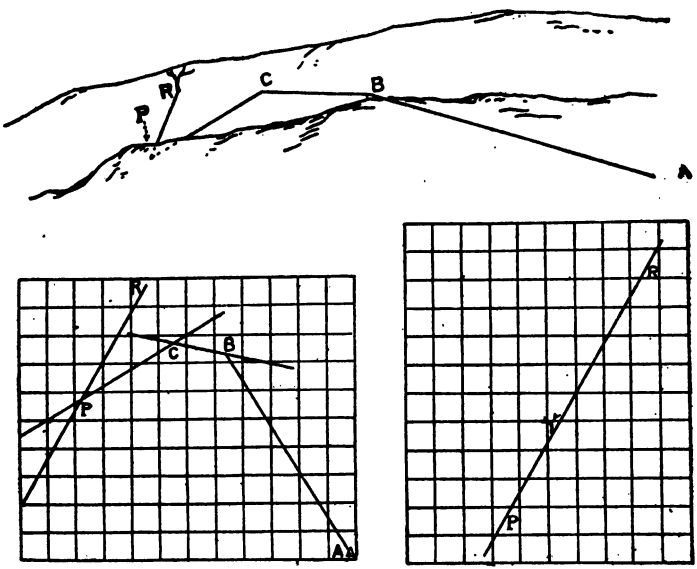
Third method: From a known point (or one easily located) there is visible a very distant known point, but the gun is not visible. The aiming line is to be determined by angle traverse. The directing gun is on a counter slope at P (fig. 31). By climbing the ridge behind the battery to a known point B—a



Plane table. Plotting board.

FIGURE 31.—Determination of aiming line from a station not visible from the battery.

boundary monument—we can see a steeple A, 9 kilometers away, but the gun is not visible. From B points are visible on the slope in front of the battery, which are also visible from the battery. Surveys will be made in the following manner:

Transfer very carefully to the plane table the points B and A by their coordinates. At C, visible from both P and B, plant a

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stake exactly upright. Occupy B, centering the plane table exactly on the center of the boundary monument (point B of plane table on the center of the boundary monument), and orient on A. Draw the line BC along the whole length of the straightedge of the instrument. Occupy C, centering exactly, orient the plane table by a back sight on the center of the boundary monument B, and sight on P, drawing CP along the whole length of the straightedge of the instrument. Do the same at P. It remains

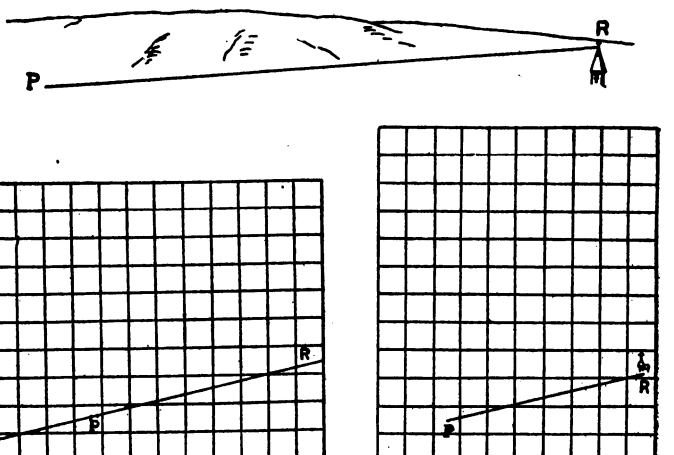

FIGURE 32.—Determination of aiming line by plane table oriented by compass.

to transfer PR to the plotting board. We can thus carry out an angle traverse of two or three stations at most.

This angle traverse may, moreover, be combined with the one for locating the gun, provided that none of its courses fall short of 50 meters, that the plane table be centered on the station within 2 or 3 centimeters, and that the lines of sight be drawn the whole length of the straightedge.

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If the number of courses of the traverse exceeds three, it will be advantageous to use the plane table and compass in locating the directing gun. In this case the error when the compass is used will be less than the error arising from the accumulation of errors in an angle traverse.[1]

Fourth method: From the directing gun an aiming point is visible but the preceding methods are not applicable, and the plane table with compass is used directly. The battery is in a valley. Up the valley a steeple R is visible halfway up the slope, and this steeple is taken as an aiming point, but it is not sufficiently distant to be plotted by its coordinates, or its coordinates are not accurately known.

The plane table, with the magnetic north line laid off on it, is set up exactly on the line PR (fig. 32), about 20 meters from the mark that indicates the goniometer of the gun. Sight on the point R and draw the line PR, using the whole length of the ruler. Prolong this line with an accurate straightedge. Transfer the aiming line to the plotting board, making use, as has been already suggested, either of the system of squares or of the protractor.

USE OF INSTRUMENTS FOR MEASURING ANGLES.

In this work an instrument for measuring angles may be used instead of a plane table—ordinarily a compass goniometer, or a compass theodolite, or perhaps a monocular telescope, a binocular telescope, or a periscopic goniometer. If it is necessary, as a preliminary, to locate a point by the three-point method, by intersection, or by resection, proceed by the ordinary methods of surveying. The coordinates will be determined either graphically or by computation. All measurements taken should be set down methodically and with great care and should be used as soon as possible—as a rule immediately upon returning from the field. A sketch giving an outline of the survey

[1] See matter in Chapter VI, "Errors in map firing," pp. 155–166.

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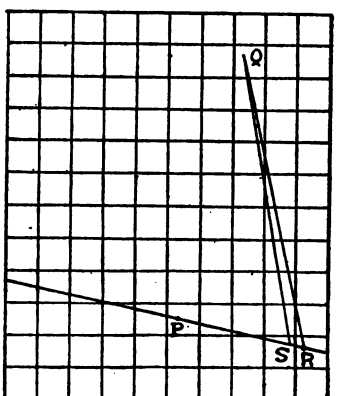
will help us in locating possible mistakes. The methods to be employed are identical with those already described.

First method: From a point which is known or can be located the directing gun is visible. This point is chosen as aiming point. The conditions are not different from those already considered. Occupy station S (fig. 33) in immediate proximity to R and exactly on the line PR. Measure SR and then measure the angle QSP, Q being a distant known point. It



Plotting board.

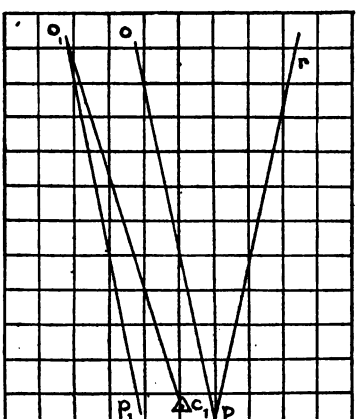
FIGURE 33.—Construction on plotting board of aiming line from angles measured with transit or other graduated instrument.

is not imperative to read the compass needle on the goniometer or theodolite, but it is convenient to do so, for the reading of the compass bearings instead of the arbitrary values of the graduation affords good checks when it comes to plotting.

The construction is made on the plotting board. For this purpose plot the two points Q and R, which are far apart, by their coordinates. Draw the line RS, either by its bearing or by making QRS=QSP, and lay off RS=the measured length. We

now have the point S. By means of the protractor plot QSP= the angle measured on the ground.

The line SP passing through the point S should pass through the line of sight of the gun. If it does not, change P slightly so that it shall be on the aiming line RSP. The line SP, plotted with the protractor, should be drawn with a good straightedge entirely across the board. The operation is the same with binocular, monocular, or periscopic goniometer.



Plotting board.

FIGURE 34.—Construction on plotting board of aiming line from angles measured with theodolite at a station not visible from the aiming point.

To solve the problem by computation it is sufficient to compute the bearing RQ and then the bearing SQ by means of a reduction to center. The axial bearing of SP is then obtained from the bearing of SQ and the angle QSP.

Second method: From a known point, or one easy to locate, the directing gun is visible but not the aiming point selected by

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the battery. Let the concrete example be that previously given for the method in which the plane table is used. Determine the coordinates of the point O (fig. 30), if they are unknown, either by graphic construction or by computation based on a round of angles taken at O with the compass goniometer, the compass theodolite (the needle being used to check calculations), or the monocular or binocular.

In making the round of the horizon at O measure the angle which the direction of the aiming instrument of the gun makes with the direction of a distant point whose coordinates are known—the steeple C, for example. The angle measured is POC.

During the topographic operation the gunner measures with the aiming circle the angle OPR between the line PO and the aiming line PR.

The plotting still remains. It should be done on the plotting board. (See fig. 34.) The gun having been represented by its coordinates at *p*, it is impossible in the present case to show the steeple *c* on the board. Shift the segment of the line *oc* by a certain number of squares so as to draw it at o_1c_1. With a protractor and a good straightedge plot the line o_1p_1 so that $p_1o_1c_1$=POC measured on the ground. Through *p* draw a parallel *po* to o_1p_1. Finally, with the usual precautions construct *opr*=the angle OPR measured with the aiming circle. On the line *pr* may be shown the position of the aiming point.

If the work is done by computation the bearing OC may be derived from the coordinates of O and of C. Adding to this bearing, with the appropriate sign, the measured values of the angles POC and OPR, we obtain the axial bearing of PR, which enables us to construct on the plotting board the straight line *pr* passing through the point *p*, previously plotted by its coordinates.

Third method: From a known point or one easy to locate there is visible a very distant known point, but the gun is not visible. The aiming line must be determined by an angle traverse. Take the concrete example previously given for the

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method in which the plane table is used (fig. 31). With the instrument used for measuring angles (compass goniometer, theodolite, monocular, or binocular) measure the angles of the traverse at B, C, and P, being careful to stake out very carefully the points occupied and to center over the stakes within 2 or 3 centimeters. Take no courses of less than 50 meters. At a less distance the error in centering on a station will affect sensibly the azimuth of the traverse. For example, 3

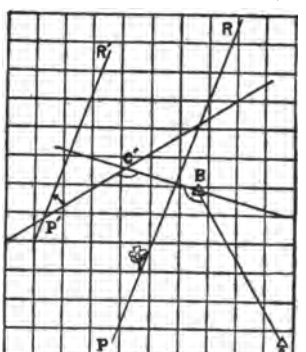

FIGURE 35.—Construction on plotting board of aiming line by angle traverse from station not visible from battery.

centimeters in a distance of 30 meters involves an error of $\frac{0.03}{30}=\frac{3}{3000}=1$ mil. It is well to use, if practicable, an instrument with a compass needle. When it comes to plotting, an approximate knowledge of the axial bearings will prevent us from laying off angles in the wrong direction.

Make the construction either on the plane table or, as shown in figure 35, on the plotting board, making use only of the squares and shifting over by a round number of squares in order to keep the construction within the sheet. Plot first A and

B by their coordinates, then BC', CP', P'R', using the protractor and a good straightedge, and drawing these lines over the whole extent of the board. It remains to draw with the usual precautions PR parallel to P'R'.

If the work is done by computation the following formula may be used, which gives the bearing of the aiming line as a function of the axial bearing V_{BA} of the line AB: $V_{PR} = V_{BA} + \Sigma$ (forward readings) $- \Sigma$ (backward readings). This simple computation is often quicker than the graphic construction.

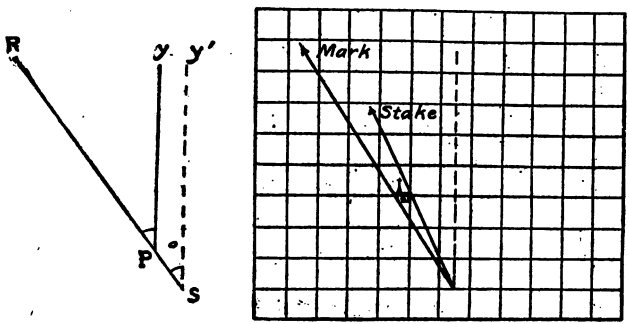

FIGURE 36.—Construction of aiming line from bearings taken with a compass goniometer.

If there are more than three courses it is advantageous to use a compass goniometer with the magnetic declination set off, and if there are more than five courses a Jobin compass theodolite.[1]

Fourth method: From the directing gun an aiming point is visible, but, if the methods already described are not applicable, it is necessary to use directly an instrument with a compass needle. Let the concrete example be the one already considered in connection with the discussion of the use of a plane table

[1] See Chapter VI, "Errors in map firing," pp. 155–166.

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(fig. 32). Use the compass goniometer or the compass theodolite with the magnetic declination set off. When the needle is on its index the telescope is directed along the axes $y\ y'$ of the Lambert squares and the limb reads zero. What it is desired to find is the bearing PR (fig. 36). It is sufficient to set up the instrument at S exactly on the line PR, some 20 meters at least from P, to orient it, and to sight on R. The reading is the axial bearing of PR. If a theodolite is used, read both verniers, and take the mean of the two readings. We may in the same way measure by a simple reading the axial bearing of a stake planted say 500 meters in front of the battery. The bearing is plotted with a protractor and a straightedge.

ASTRONOMIC METHODS.

In a region in which there are no control points that permit the making of accurate locations or the determination of the magnetic declination, resort may be had to astronomic methods to fix the direction of the aiming line. These methods require the use of the heavy artillery theodolite. Observe either the sun or Polaris, and from the computed azimuth deduce the axial bearing of the aiming point sighted in the course of the work.

DETERMINATION OF THE AIMING LINE BY THE COORDINATES OF THE AIMING POINT.

If from the position of the directing gun there is visible a clearly defined point of the general control, such as a steeple or a solitary tree—not a corner of a wood—it may be chosen as an aiming point and be plotted on the board by its coordinates. The aiming line will be defined by the straight line joining the position of the gun and this control point.

It is necessary to know whether the control point may be considered sufficiently distant to use the method indicated above. The following table gives for an error E in the relative positions of the gun and of the point the maximum angular error to be

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expected in mils and in decigrads, D being the distance from the battery to the point.

Angular errors corresponding to linear displacements at given distances.

D (distance in meters).	E=10 meters.		E=20 meters.		E=30 meters.		E=40 meters.		E=50 meters.	
	Decigrads.	Mils.	Decigrads.	Mils.	Decigrads.	Mils.	Decigrads.	Mils.	Decigrads.	Mils.
1,000	6	10	12	20	19	30	25	40	31	50
1,500	4	7	8	13	12	20	17	27	21	33
2,000	3	5	6	10	9	15	12	20	16	25
3,000	2	3	4	7	6	10	8	13	10	16
4,000	.....	.....	3	5	5	8	6	10	8	13
5,000	.....	.....	2	4	4	6	5	8	6	10

It appears that in no case should the aiming line be defined by a control point whose position is known by its coordinates if the distance D is less than 1,000 meters. It should be noted that the mere plotting on the board of the coordinates of the gun and of the point involves for each an error which may be as much as 10 meters and which may involve an error of 20 meters in the relative position of the two points—that is, at 1,000 meters an error in azimuth of 12 decigrads, or 20 mils. In each particular case the above table will enable us to decide whether the point is sufficiently distant to permit it to be used for aiming or whether it is necessary to use one of the methods indicated above.

If the distant point can not be shown on the plotting board, shift this point and the position of the directing gun by the same amount, subtracting from or adding a round number of kilometers to the coordinates of the gun P and of the point R. (fig. 37). Plot the points P′ and R′ with the modified coordinates and draw through P a line parallel to P′R′ with the help of the squares. If R is directed toward the rear, place P′ near the front of the board and R′ near the rear.

If the aiming point is so far distant that the construction can not be made even by shifting, the line may be drawn in the following manner: Let x and y be the coordinates of the gun, x' and y' those of the aiming point. Construct a right triangle with its sides parallel to the axes ox and oy of the squares and, respectively, equal to $\frac{x'-x}{2}$ and $\frac{y'-y}{2}$ $\left(\text{in general } \frac{x'-x}{n} \text{ and } \frac{y'-y}{n}\right)$. The hypotenuse will then give the direction of the aiming line.

If a control point with known coordinates is not sufficiently

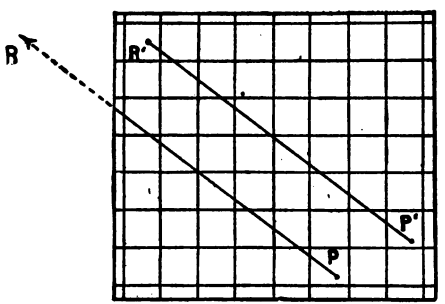

FIGURE 37.—Method of shifting aiming line to distant aiming point on plotting board.

distant to establish an accurate aiming line, such a line should, as has been stated above, be determined directly by one of the methods already given. In that case certain apparent discrepancies may be found. If the positions of P and R (fig. 38) are absolutely exact and if the aiming line is determined with absolute correctness, its trace, if drawn from P, must obviously pass through R. But in reality this will not be the case, for the relative positions of P and of R are susceptible to error. Unless, indeed, a mistake has been made, it is best not to disturb the aiming line but to consider it accurate. What should be done is either not to put R on the aiming line passing through P or to

make an arbitrary adjustment by putting one of the two points P or R on the aiming line passing through the other. We will thus be led to modify slightly the coordinates of either P or R. Which point is it better to move, P or R? The answer to this question will depend on circumstances and on the confidence had in the accuracy of the coordinates of R and P. In general, if R is a point of the general control, it is the one that has the most reliable coordinates, those of P being based on fairly long

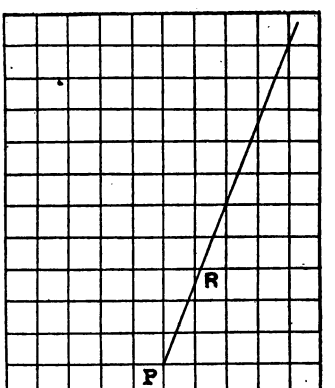

FIGURE 38.—Exact construction of aiming line.

surveys made with instruments less accurate than those that served to determine the coordinates of R. The simplest method is to locate P on the aiming line passing through R. Change, therefore, the position of P to P′ in such a way that the displacement will be a minimum. PP′ will then be perpendicular to the aiming line. (See fig. 39.)

If, on the contrary, the start was made from a point of the general control not far distant from P (200 meters, for example), and if we have closed upon another point of the gen-

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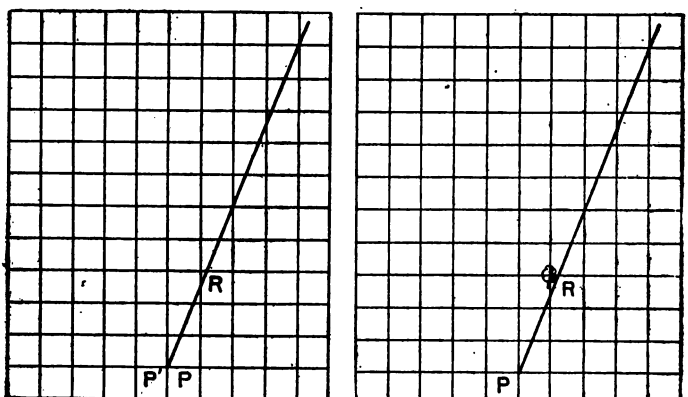
eral control at about the same distance from P, and if the closure is small (5 meters), P may be considered as well located. But if R is not a point of the general control, but only a point on the topographic map, there is reason to suppose that its coordinates are not very accurate. It is best then to draw the aiming line through P and to represent R only in profile (as it appears from the directing gun), alongside of the aiming line and near its position (see fig. 39).



The aiming line is drawn through R.

The aiming line is drawn through P.

FIGURE 39.—Aiming lines drawn arbitrarily through selected points.

DIRECT AIMING OF THE DIRECTING GUN BY TOPOGRAPHIC OR ASTRONOMIC METHODS.

The directing gun must be aimed by topographic or astronomic methods when the battery is in a wood or at the bottom of a ravine—that is, without outlook—or when it is in a region where there are no control points or if the work must be done by night.

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OPERATIONS BY DAY.

Use of the plane table and compass.—Draw on the plane table the line directing gun–target. This may be done by transferring the coordinates of the gun and of the target, if the target can be located on the plane table, or by transferring the direction PB taken from the plotting board with a protractor from the point P. Having marked the magnetic declination on the plane table, set up as far as possible from the gun (20 meters at least), on a point from which the goniometer may be sighted. Orient the plane table very carefully with the needle. Aim the gun as accurately as possible.

With the leveling alidade (or with the clinometer rule) sight on the goniometer P (fig. 40), and draw the line of sight PS the whole length of the straightedge, without, however, marking the point S. Measure with the protractor the angle BPS, and lay

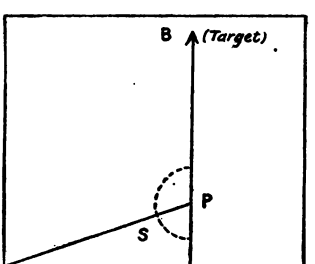

FIGURE 40.—Orientation of gun by plane table and compass.

it off on the goniometer as 1,350, for example. Aim the gun by means of a pencil held vertically on the point P on the plane table. Repeat the operation once or twice in order to take account of the displacements of the gun during the aiming, displacements which become more and more insignificant. The gunner then aims his gun under conditions that seem to him best.

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Use of the compass goniometer or the compass theodolite.—Having previously set off the magnetic declination on the compass goniometer by reference to the Lambert squares, set it up at least 40 meters from the gun and orient it. Only the red graduations, which give the axial bearings directly, are to be used.

Measure on the plotting board the angle which the line gun–target makes with the line *oy* of the Lambert squares (fig. 41), this angle A being measured in clockwise direction. Point the compass goniometer on the standard of the aiming circle of the gun, take a reading B (on the red graduations, as has been said), and point the gun on the compass goniometer with the

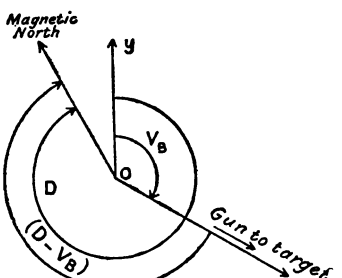

FIGURE 41.—Angle to be laid off on aiming circle.

reading B—A. Repeat the operation until the reading B of the compass goniometer no longer changes.

For the 75-millimeter gun, for which more particularly the compass goniometer is constructed, it is convenient to use the following method, which enables us to give immediately to the gunner the deflection to be laid off on the aiming circle for reciprocal aiming on the compass goniometer.

Let D (fig. 41) be the declination taken on the red figures (axial bearing of magnetic north) of the apparatus used, and V_B the axial bearing of the line gun–target (V_B is the angle designated by A in the notation above).

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Lay off on the red graduations the reading $D-V_B=$ the angle between the magnetic north and the line gun–target, measured in the direction of increasing bearings.

Bring, with the help of the general motion, the magnetic needle to its mark. At this time the zero of the graduation lies along a line parallel to the line gun–target. Pointing then on the apparatus of the gun, read on the upper graduations opposite the triangular index of the lower graduations the deflection to be laid off by the gunner on the plate (main scale) and the drum (azimuth micrometer). Repeat the operation once or twice.

The operation performed with the compass theodolite is entirely similar to that performed with the compass goniometer. The direction of the graduations of the theodolite and of the aiming circle should be taken into consideration and an appropriate rule established in each case.

Angle traverse with plane table or with an instrument for measuring angles.—The two methods just described may be used with the plane table or an instrument for measuring angles by making an angle traverse, in order to make sure of the orientation of the instrument used.

Astronomic method; use of the sun.—If we are in a region where there are no control points that will enable us to find the magnetic declination of the instruments, we may, as in determining the aiming line, resort to the sun in order to aim the directing gun directly. The operation requires a theodolite.

OPERATIONS AT NIGHT.

Use of lanterns.—The position of the gun should have been determined by daylight or clearly indicated. In any case, it is always possible to carry out by night a short traverse starting from known points. What remains to be determined before opening fire is mainly the direction of the gun. It will always be possible to determine its position more exactly, if necessary, at daybreak. A parallel line drawn through the corrected position will solve the problem completely. To determine the direc-

tion use one of the methods given for daylight determinations by making provision for the illumination of the instruments and the points sighted on. In the astronomic method we substitute polaris for the sun. With the compass goniometer it is also possible to resort to the following method: Take one of the aiming lanterns, 1915 model, place it approximately on the line gun–target, and indicate by a sighting stake the position of the aiming circle. Align the compass goniometer upon the line goniometer–lantern, placing it some 50 meters in the rear (fig. 42). When the gun is put in position, make it parallel to the goniometer aimed on the target, as has already been said. Aim the gun by means of the aiming lantern. Then move the

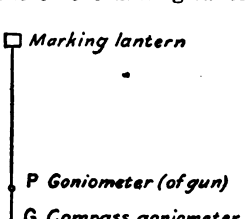

FIGURE 42.—Alignment of compass goniometer with goniometer of gun and lantern.

aiming lantern, if desired, before aiming on a final aiming point, taking care not to disturb the gun during this operation before finally accepting the marking. This mode of working is somewhat quicker for the battery.

Astronomic method; use of Polaris.—Polaris is very nearly on the meridian. Its direction makes with the meridian an angle, called azimuth, which depends on the time, the date, and the place. In our part of the world this azimuth may attain 20 decigrads (32 mils). Diagrams taken from the "Connaissance des temps" (official French Ephemeris and Nautical Almanac) give the azimuth and the necessary rules for determining it for a known hour, date, and place. The instruments that may

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be used are the theodolite, which is very accurate, and the goniometer of the gun, with collimator. The line of sight is high above the horizon. The essential precaution to be observed is to make sure that the axis of the instrument is strictly vertical, in order that the azimuth readings may not be in error.

MISCELLANEOUS OPERATIONS REQUIRED OF ORIENTATION OFFICERS.

STUDY OF THE GROUND AROUND THE BATTERY.

When the orientation officer reports to a battery to do topographic work he is careful to map all the features near the battery and to make all measurements that may be useful. These measurements may be made in a few minutes with a compass goniometer or a compass theodolite.

To avoid errors and to insure simple and brief expression points sighted should be described mainly by their axial bearings. The orientation officer sets up his goniometer in the emplacement of the directing gun and orients it; then he measures

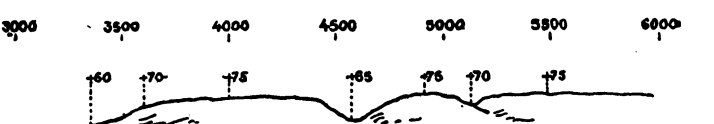

FIGURE 43.—Panoramic sketch with marked heights and angles of site at critical points.

the angle of site of the crest of the mask in certain directions—the usual or principal directions of fire, the axial bearings of which are given by the battle map or the topographic map, and the directions for which the angle of site changes sign or varies abruptly in amount.

All these measurements are best shown on a sort of panoramic sketch of the mask (fig. 43). This sketch will be used to determine the possibilities of fire by the battery. The orientation officer may also measure the amount of defilade of the guns in meters, with reference to a point A in the enemy zone.

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LAYING OUT A MEDIAN LINE OF FIRE.

In connection with the construction of a battery the orientation officer may be required to lay out on the ground the median line of fire from the emplacement. This problem is the reverse of that of determining the aiming line, which requires the drawing on the map of a direction represented by objects on the ground.

Draw on the battle map or on the topographic map the median line of fire decided on, and measure its axial bearing with a protractor. Set up in the emplacement of the gun an instrument with a magnetic needle, orient it, and have set out a sufficient number of stakes in the direction determined by the axial bearing of the median line. Except in very special cases the operation does not require extreme accuracy. The Peigné compass, the compass goniometer, or the plane table with leveling alidade may be used.

DETERMINATIONS OF POSITIONS OF OBSERVATION STATIONS.

The operations for determining the positions of observation stations are identical with the operations performed for batteries, but as most observation stations are situated at points where there is a wide outlook, it is often easier to determine them by the three-point method or by intersection. Always ascertain whether there is not in their neighborhood a point of the general control from which a very rapid and accurate location can be obtained. The main resection stations of the artillery observation sections are determined with very great accuracy by the range triangulation detachments.

DETERMINATION OF AUXILIARY TARGETS.

The position of auxiliary targets can be determined only by intersection or by identification on a map, which, however, requires intersections. The points occupied will in general be

observation stations, but exceptionally they will be distant points where an instrument can be set up. The greatest difficulty is in identifying with certainty the same point when sighting from different stations. Auxiliary targets are seldom clearly defined or seldom seem so when seen from different directions. When they are unmistakable they are picked out by several batteries, and their destruction is almost certain. In general, we have to be satisfied with using some point in a trench or a crossroads. If the positions of the observation stations are well determined the identification or determination of these points will be sufficiently accurate.

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CHAPTER V.

COMPUTATION OF THE INITIAL FIRING DATA.

The determination of the initial firing data by means of maps and range tables, both when no account is taken of the meteorologic corrections and when these corrections are made, will now be considered. This determination is essentially the work of the battery commanders, but nevertheless it can not be ignored by the orientation officers (1) because they may be required by the major to study the fire records of the batteries, particularly the fire records of batteries that have left the sector, and (2) because the magnitude of the errors in fire and the possibility of reducing them are intimately connected with topographic operations, and only a knowledge of such operations will enable them to choose the topographic methods that should be employed in battery surveys.

DETERMINATION OF THE FIRING DATA WITHOUT METEOROLOGIC CORRECTIONS.

DIRECT DETERMINATION OF THE INITIAL FIRING DATA ON A TARGET.

When the position of the directing gun and the aiming line have been determined, transfer them to the plotting board. Then locate the target on it by its coordinates. The plotting may be done also on the battle map. Join the target to the directing gun and measure by the protractor the angle A between the line gun–aiming point and the line gun–target. Next measure to within 10 meters, with a zinc ruler or a double decimeter scale, the distance from the target to the directing gun. Divide the difference between the altitude of the target

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and the altitude of the directing gun by the topographic distance expressed in kilometers, thus obtaining the angle of site, expressed in mils, with the correct sign.

With these data taken from the map, the range tables will enable us to obtain the real firing data, namely, the graduations to be laid off (*a*) on the range quadrant (for the 75-millimeter gun,[1] the angle of elevation is laid off in minutes or in twentieths of a degree of elevation), the site and the complementary correction for site being taken into account if necessary; (*b*) on the aiming circle for direction, the drift being taken into account.

DETERMINATION OF THE INITIAL FIRING DATA BY TRANSFER OF FIRE; COEFFICIENT OF ADJUSTMENT K.

Transfer of fire consists in determining, by means of results obtained from perfectly adjusted fire on a certain target (the auxiliary target) the data for fire on another target (the real target), which is not susceptible of continuous observation.[2] The second fire should closely follow the first, and the same lot of powder and projectiles should be used. The two are then affected by the same disturbing causes. The positions of the two targets should be perfectly known, and both targets should be within a rather small area—that is, the range to the real target should be between three-fourths and four-thirds of the range to the auxiliary target, and the angle between the two targets should be less than 200 decigrads in order that the following rules may apply:

1. The corrections in deflection are the same.

[1] In firing cartridges other than shrapnel (model 1897) with the 75's, the elevating drum is an instrument analogous to a level. It enables us to give the tube the angle of elevation desired in order to attain a target, but in no way indicates the distance to this target.

[2] See Provisional gunnery instruction [Instruction provisoire sur le tir] of May 15, 1915, pp. 39 and 92.

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2. The range to the real target is equal to the coefficient of adjustment deduced from fire on the auxiliary target multiplied by the topographic range to the real target.

The coefficient of adjustment K is, by definition, the ratio of the adjustment range D, reduced to the horizontal, to the topographic range A of the auxiliary target: $K=\frac{D}{A}$.

The battery commander prepares his fire on the auxiliary target, as has been stated in the preceding paragraph. He adjusts on this target, which is susceptible of easy and continuous observation. From the results of this fire he deduces the value of the coefficient K. He records the graduation Δ to be laid off on the aiming circle.

He measures on the board the angle δ between the auxiliary target and the real target and the difference a between the topographic ranges of these two targets. This operation is easily performed with the protractor. He obtains the topographic range $A'=(A+a)$ to the real target, whence he deduces the range KA'. He also calculates the site. With the aid of these data, transformed by means of the range tables, he has the data for his fire as regards range. The division to be laid off on the aiming circle is $\Delta+\delta$.

It should be observed that this operation of transferring fire is especially advantageous from the topographer's point of view. It diminishes, to a large extent, the errors arising from a defective determination of the position of the directing gun by the simple fact that the auxiliary target, which becomes a tie point for the fire, makes a very favorable point of reference, precisely on account of the restrictions imposed in choosing it.

If the positions of the auxiliary target and the real target are accurately given on the maps, and if, furthermore, the transfer of fire is made under theoretical conditions, the influence of the topographic error made in determining the position of the gun is practically negligible; but this is by no means true of a fire which has not been transferred and the data for which

must be obtained by a direct measurement on the map by the use of an aiming line.[1]

DETERMINATION OF THE INITIAL FIRING DATA BY MEANS OF A REFERENCE TARGET.

Fire must often be directed on targets that are invisible to the battery command, as when, for example, the adjustment is made by airplanes without the possibility of preparing the fire with the help of an auxiliary target that fulfills the conditions required with regard to the real target. If the battery commander desires to have it within his power to resume, with only his own resources, a fire of this sort, he seeks a plainly visible target (the position of which may not be locatable on the battle map), and makes an adjustment on this target, called a reference target, which should be as near as possible to the real target. The comparison of the results of successive adjustments on the target and on the reference target enables him to deduce by the fire, without the battle maps, the angle between the reference target and the real target and the difference between their ranges.

For further firing the reference target can be used as an auxiliary target. Transfer of fire will be made by applying the same rules but by considering the adjusted ranges obtained in the first fire as equivalent to the topographic ranges.

FIRE THAT CAN NOT BE OBSERVED.

When fire for effect can not be observed the preparation for fire is made, as has been said, by using as intermediary an auxiliary target or a reference target. If the fire consists of a large number of rounds, or if it is often repeated, ask for the photographs necessary to verify the results obtained. This course is indispensable for firing by night on roads, intersections of roads, etc. The photographs often show that, for reasons that are

[1] See Chapter VI, "Errors in map firing," pp. 155–166.

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generally impossible to determine, the rounds are not grouped on the area which it is desired to reach. This fact will be taken into consideration in further firing, and better results will be attained.

UTILIZATION OF PREVIOUS FIRE.

In proceeding in the way indicated above it is necessary to be very cautious in using previous fire for adjustment on a target. By reason of the meteorologic conditions of the moment, the data obtained from previous fire permit only zone fire, fire on very large targets, and barrage fire; and the results of the transfer of previous fire or of fire with the use of a reference target, can not be used without new adjustment for precise firing. The influence of meteorologic perturbations can be eliminated for a given moment by the use of the coefficient of adjustment, but we can not hope to get good results at another given moment without repeating the same operations, for K varies too much with the conditions of the moment. The entry in the range notebooks of the coefficient of adjustment K and of the adjustment range D provides something to go by that enables a more rapid performance of the operations to be repeated at each fire, but that is all. To use the results gained by previous adjustments to the greatest advantage it is best to employ another method, which takes into account the meteorologic corrections, as shown below.

DETERMINATION OF THE FIRING DATA WITH METEOROLOGIC CORRECTIONS.

CORRECTIONS TO BE APPLIED TO THE DATA DETERMINED FROM THE MAPS.

The initial firing data having been determined by means of the map, the corrections that modify them are the following:

In direction; For drift; the correction for lateral wind dW_y.

In range: The correction dV_0 for variation of the mean initial velocity given by the lot of powder used; the correction

dP for variation of the weight of the projectile; the correction $d\varpi$ for variation of the weight of a liter of air; the correction $d\mathrm{W}_x$ for longitudinal wind.

The sum of the four corrections last named, added to the topographic range A of the target, gives the computed adjustment range, which is equal to $\mathrm{A}+d\mathrm{V}_0+d\mathrm{P}+d\varpi+d\mathrm{W}_x$.

This adjustment range, modified by the total correction for site (sité and supplementary correction for site), gives the range table range to be used. As has been previously stated, this range table range, which appears in the first column of the ballistic tables, is transformed either into angle of elevation or into graduations of the elevating drum or twentieths of a degree of elevation.

CORRECTION FOR INITIAL VELOCITY.

The powder factories undertake to regulate the charges so as to obtain very nearly the range-table velocity. That velocity, however, is an average annual velocity, for velocities are greater in summer and less in winter. The variation in velocity assumed to be due to a variation in temperature may be evaluated by the formula [1]—

$$d\mathrm{V}=0.001(t-15)\mathrm{V}$$

The correction in the range resulting from the variation of the initial velocity is calculated according to the information given in the tables.[2]

[1] Some reservations should be made in regard to this formula.

[2] The brief provisional ballistic tables for explosive shells fitted with fuses I and IA and fired with a muzzle velocity of 550 meters, 75-millimeter gun, model 1897, Aug. 12, 1916 [tables de tir sommaires provisoires des obus explosifs armés des fusées I et IA et tirés à la vitesse initiale de 550 mètres, canon de 75, modèle 1897, 12 août 1916]. Also the ballistic tables for 155-millimeter guns, 1877, and model 1877–1914, Mar. 27, 1916, and other tables later than February, 1917 [tables de tir de canons 155 L, modèle 1877, et modèle 1877 à 1914 du 27 mars 1916, et autres tables postérieures à février 1917].

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Examples: 1. A 75-millimeter explosive shell fitted with fuse I [instantaneous] and fired with a velocity of 550 meters. If the topographic range is 5,000 meters and the temperature is 25° C., the variation in velocity is—

$$dV=0.001(25-15)550=5.5$$

For 5,000 meters a variation $dV_0=10$ gives a variation in range of 71 meters. The variation in range will therefore be—

$$7.1\times5.5=39 \text{ meters}$$

and the correction to be applied is —39 meters.

2. Semisteel shell model 1915, or 155-millimeter gun, model 1877–1914, charge 1, topographic range 8,000 meters, temperature —5°. The variation of the initial velocity is—

$$dV=0.001(-5-15)392=7.84$$

For 8,000 meters a variation in the initial velocity of +10 meters involves a variation in the range of the same sign of 251 meters. The variation in the range will therefore be—

$$25.1(-7.84)=197 \text{ meters}$$

and the correction is +197 meters.

These two examples of calculations are given only as illustrations. In reality the variation in the initial velocity depends on the gun, the lot of powder, and the season (or the temperature). It is almost impossible to evaluate this variation a priori. Consequently in everything that follows it must be determined by adjustment. (See on p. 128 the definition of K_0.)

CORRECTION FOR VARIATION IN THE WEIGHT OF THE PROJECTILE.

Most range tables for shells of different calibers give, for each range, the variation in range due to an increase of 100 grams in the weight of the projectile. The calculation of the

variation in the range and of the correction presents no special difficulty.

In the brief provisional range tables for explosive shells fitted with fuses I [instantaneous] and IA [instantaneous, long], initial velocity of 550 meters, we find, for a projectile fired at 6,000 meters with fuse IA, that for $dP_0=100$ grams the variation in range is +22 meters; if we have a projectile 250 grams less than the normal weight the variation in range will be—

$$0.22(-250)=-55 \text{ meters}$$

and the correction is +55 meters.

The shells are marked with letters, figures, or crosses, enabling us to tell approximately the difference between their weight and the normal weight, and consequently to calculate the corrections. Shells of the same lot are, in theory, of the same weight.

ATMOSPHERIC CORRECTIONS.

NECESSARY DATA.

Atmospheric corrections are due to the variation in the weight of the air and to the influence of the wind. The data necessary to calculate them are (1) the temperature and pressure taken at the gun, (2) the force and direction of the wind.

These data are determined every day at the meteorologic station of the army and transmitted as a telephone message giving (1) the temperature and pressure at the station, either referred to the level of the sea or referred to the mean level of the region—100 meters, 200 meters, 300 meters; (2) the force and direction of the wind, as, for example, to the nearest 100 meters up to 600, to the nearest 200 meters from 800 to 1,400, to the nearest 500 meters above 1,500.

The data are given in units of the following system: The circumference of a circle at the point of observation is assumed to be divided into 40 equal parts, numbered from 1 to 40,

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in clockwise direction, the numbering beginning at the geographic north. The wind blows from the circumference toward the center. Thus wind No. 15 blows from the southeast.

If the battery has neither barometer nor thermometer, it will be necessary to accept as accurate the temperature received, and to modify the barometric pressure by taking into account the difference in altitude between the battery and the meteorologic station. On an average, an increase in altitude of 11 meters corresponds to a decrease of 1 millimeter in the pressure.

The corrections are made either with the help of the information contained in the ballistic tables or with the help of the appendix to the range tables of February 2, 1916 [Annexe aux tables de tir du 2 février, 1916]. The new editions of the tables contain all the diagrams and data needed to calculate these corrections. It is only when one of these editions is not at hand for the caliber employed that the appendix to the range tables is used.

CORRECTIONS FOR THE VARIATION IN THE WEIGHT OF THE AIR.

With the appendix to the range tables of February 2, 1916, this correction is calculated by means of the two tables, A and B. Table A is a double-entry table, with temperature and pressure as arguments. It gives the value of the coefficient A, which is simply the excess above 1,208 grams (the normal weight of a liter of air) of the weight of a liter of air at the temperature and pressure considered. This excess is expressed in centigrams. Table B consists of single-entry tables giving, for each gun and for each kind of charge and projectile, the coefficient B, which is the value of the correction corresponding to a change of 1 centigram in the weight of a liter of air. The product of A×B gives the correction sought, a correction to be applied to the topographic range in order that the projectile may fall on its target if there were no other correction to be made.

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Suppose a 75-millimeter explosive shell is to be fired on a target at a topographic range of 5,000 meters, the battery being 44 meters above the meteorologic station. The data sent in by the station are temperature —6°, pressure 774 mm. The data at the gun will be temperature —6°, pressure $774-\frac{44}{11}=770$. We find, for the coefficient corresponding to —6° and +770, A=+10.9. In Table B we find for the 75-millimeter explosive shell at 5,000 meters B=19, whence the correction $10.9\times19=207$ meters. The corrected range will be 5,207 meters. Table B gives the coefficient B for the greater part of the matériel in use. For all this matériel the calculation of the correction is similar.

With the new range tables the calculation is made as follows: In the tables there is a diagram giving, for a definite temperature and pressure, the variation in milligrams of the weight of a liter of air (mean humidity $\frac{1}{2}$). This diagram is the same for all range tables. The tables also give, for ranges varying by a thousand meters, either the variation in range for a variation of 0.1 gram in the weight of a liter of air (brief provisional ballistic tables for the 75-millimeter gun, Aug. 12, 1916; 155-millimeter range tables, Mar. 27, 1916, or the correction for range (with the proper sign) corresponding to variations in the weight of a liter of air at intervals of 10 milligrams (105-millimeter gun).

Below are three examples. In them we suppose the temperature to be 21°, the pressure 760 millimeters. The diagram gives $d\omega=-0.011$ gram.

First example: 75-millimeter gun, fuse I, initial velocity 550, topographic range 5,000 meters. We find, on page 5 of the range tables, that for an increase of 0.1 gram the variation in range is —161. For a decrease of —0.011, the variation will be $-0.011\left(\frac{-161}{100}\right)=+18$ meters. The correction to be applied to the distance will be then —18 meters.

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Second example: 105-millimeter gun, explosive shell, topographic range 10,000 meters. In the range tables of February 19, 1916, we find, in Table IV, page 8, that at 10,000 meters, for a variation of —20, the correction is 63 meters, and at 10,000 meters for a variation of 0, the correction is 0 meters; for a variation of 20, it is 63 meters. We have, then, as a correction, $\frac{63-0}{20}\times 11=35$ meters. Furthermore, the table shows that the real range is greater than the range-table range. The topographic range should therefore be decreased by 35 meters.

Third example: 155-millimeter gun, model 1877–1914, topographic range 10,500 meters; charge, 000; elongated shell, model 1914. The variation in the range at 10,500 meters due to a variation of 0.011 gram is

$$\left(\frac{326+290}{2}\right)\times\frac{11}{100}=34 \text{ meters}$$

(See Table VI, pp. 132 and 133, of the range tables of Mar. 27, 1916.) The topographic range should be diminished by 34 meters.

CORRECTIONS DUE TO WIND.

In the correction to be made for wind, as in other meteorologic corrections, the computation is made by means of the range tables, and, if these do not contain the necessary information, by means of the appendix to the range tables of February 2, 1916.

Computation of the components of the wind.—The data for the wind (force and direction) at various altitudes are furnished by the meteorologic service, as has been already stated, but it is necessary to calculate the components along the line of fire and in the direction perpendicular to it.

Simple diagrams enable us to determine the components at once. We may also draw in advance on the battle map a 10-centimeter circle with its center at the battery P. We divide this circle into 40 equal parts, starting from the north, with

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the help of a protractor divided in grads, and number the points of division 1 to 40, in clockwise direction. We adopt the scale of 1 centimeter to the meter. For example, we wish to fire on the point B and we have a wind whose direction is 8 and whose force is 7. (See fig. 44.) Draw the line PB and the line joining P to 8. Lay off PV equal to 7 centimeters. Project V on PB at T; TP will be the longitudinal wind and TV will be the transverse wind. The correction for the longitudinal wind will be posi-

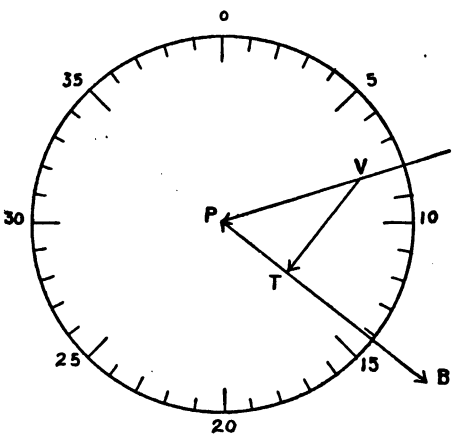

FIGURE 44.—Graphic method of determining the components of the wind.

tive when the point T falls between P and B, negative in the opposite case. The correction for the transverse wind will have different signs according as V falls to the right or to the left of PB. The sign depends on the aiming apparatus used. For the 75-millimeter gun the correction is positive when V is on the left, negative when V is on the right.

Corrections by means of the range tables.—The range tables include tables giving corrections for range and for deflection

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corresponding to various ranges (intervals of 1,000 meters, or less) for a longitudinal wind of 10 meters and for a transverse wind of 10 meters. Their use presents no difficulty. The only trouble is to determine the force and the direction of the wind that should be used.

The wind may be subject to considerable changes in force and in direction, according to altitude, particularly when it is light (velocity less than 4 meters at the ground). In general, however, when its force is perceptible (velocity greater than 5 meters at the ground) its direction varies but little (1 to 4 decigrads) at altitudes between 500 and 2,000 meters, which is the principal zone of the trajectories, and its velocity changes in a fairly continuous way within the same interval.

It has become customary to assume that the effective wind—that is, the wind that should be considered in computations of the correction—is that which prevails at a certain altitude taken as equal to two-thirds, three-fourths, or four-fifths of the maximum ordinate of the trajectory. But in reality it is impossible to provide an accurate rule that applies to all conditions. The above general rule does not sufficiently allow for the effect of the wind at the origin of the trajectory, which plays an important part in the deviation due to the wind. This effect, in short, modifies the resistance of the air and the influence of this resistance in reducing the range which would be obtained in vacuo with the same initial conditions. It makes itself felt in the first part of the trajectory particularly; in the first place, because of the greater value of the velocity (and consequently of the resistance); in the second place, because of the fact that the modifications of the motion thus introduced at the beginning react on the entire trajectory.

When the velocity and direction of the wind are given for various altitudes, the component W_x, calculated with the help of a diagram, will assume, between the altitude of the gun and the summit of the trajectory, some minimum value $(W_x)m$ and some maximum value $(W_x)M$. By adopting for the effec-

tive wind one of these extreme values, we obtain a maximum or a minimum correction. If we take

$$\frac{W_x=(W_x)m+(W_x)M}{2}$$

the error committed will be at most equal to the variation in range resulting from a uniform wind—

$$\frac{(W_x)M-(W_x)m}{2}$$

To take into account the special effect of the wind near the ground $(W_x)o$ we may take as the effective wind in the direction of the plane of fire an expression such as—

$$\frac{(W_x)m+(W_x)M+(W_x)_o}{3}$$

If the various components of W_x are not all in the same direction they must of course be taken with algebraic signs. In this case, $(W_x)m$ and $(W_x)M$ are necessarily of opposite signs, and equal to the greatest absolute value of the component observed in each direction.[1]

The above considerations apply more particularly to corrections in range due to the longitudinal component, but in practice there is nothing improper in proceeding in the same way to determine the transverse component.

COEFFICIENT OF ADJUSTMENT K_o; REPETITION AND TRANSFER OF FIRE.

DEFINITION.

As has been already stated, if we carry out a series of fires for adjustment on the same target and with the same lot of ammunition but under different atmospheric conditions, the

[1] The information and other data here given have been taken from range tables now in preparation.

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deflections, the ranges, and the adjustment ranges obtained will not be the same. If we wish to use these results to conduct other fire, it is necessary to reduce the elements obtained to what they would have been if the fire had been executed under normal atmospheric conditions. The atmospheric conditions adopted as normal are those used in constructing the range tables, namely, weight of a liter of air (1.208 grams) at zero wind.

After fire for adjustment, we calculate the deflection for wind and drift, the range corrected for atmospheric conditions, and the adjustment range corrected for atmospheric conditions. It is from this last element that the coefficient of adjustment K_0 is deduced, the definition of which is therefore changed and becomes the following:

The coefficient of adjustment is the ratio of the adjustment range as modified by atmospheric conditions to the topographic range.[1] This coefficient characterizes the various lots of powder used, if the charges are associated with projectiles of the same weight.

DEDUCTION.

Let P be the range-table range corresponding to the corrected quadrant angle of elevation:

$$P=(A+dV_0+dP+d\varpi+dW_x)+S.$$

A=topographic range.

dV_0, correction for the initial velocity[2]

dP, correction for the weight of the projectile

$d\varpi$, correction for the weight of a liter of air

dW_x, correction for the wind

} Calculated with the argument A.

[1] This is the range which the fire notebook for heavy artillery [Carnet de tir de l'artillerie lourde] calls "the theoretical range reduced to the zero corrections" [distance théorique ramenée à corrections nulles].

[2] "Correction for the initial velocity" is the correction for range resulting from the variation of the initial velocity.

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S is the total site increment, calculated with the argument $(A+dV_0+dP+d\varpi+dW_x)$. The adjustment range D[1] has for its value—

$$D=P-S=A+dV_0+dP+d\varpi+dW_x$$

If we put $M=d\varpi+dW_x$ we have—

$$D=(A+dV_0+dP)+M$$

Let us call D_0 the adjustment range corrected for atmospheric conditions.[2] We have—

$$D_0=D-M=A+dV_0+dP$$

If we call K_0 the coefficient of adjustment as defined above—

$$K_0=\frac{D_0}{A}=\frac{A+dV_0+dP}{A}=1+\frac{dV_0}{A}+\frac{dP}{A}$$

We see that, allowing for the uncertainties of the atmospheric corrections, the coefficient K_0 depends only upon $\frac{dV_0}{A}$ and $\frac{dP}{A}$—that is to say, on the initial velocity of the lot of powder and on the weight of the projectile used. So long as A varies but little the quantities $\frac{dV_0}{A}$ and $\frac{dP}{A}$ will vary but little. K_0 may therefore be considered a constant for ranges near the range A for a given lot of powder associated with projectiles of the same weight.

USE OF THE VALUE OF K_0.

Finally, from previous fire there are retained the deflection reduced to normal conditions, the range reduced to normal conditions, and the coefficient of adjustment K_0 characteristic of the lot. The first two will be used when fire is reopened on the same target with the same supply of ammunition. It will suf-

[1] Range corresponding to the adjustment angle of elevation reduced to the horizontal—that is, modified by applying the total correction for site, with the proper sign.

[2] Also termed the theoretical range reduced to zero corrections.

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fice to correct them for the atmospheric conditions of the moment. As to the coefficient of adjustment, it will be used when fire is opened on another target whose range does not differ too much from A.

For this purpose measure the topographic range A′ from the gun to the new target. With A′ as argument, compute the correction due to the atmospheric conditions of the moment, $M'=d\varpi+dW'_x$. Compute the quantity $K_0A'+M'$, which gives the adjustment range, and from it deduce, by the correction for site, the range-table range corresponding to the corrected quadrant angle of elevation.

Deduction:

$$K_0A'=A'\left(1+\frac{dV_0}{A}+\frac{dP}{A}\right)$$

By hypothesis, since A′ does not differ very much from A, we may write

$$\frac{dV_0}{A}=\frac{dV_0'}{A} \text{ and } \frac{dP}{A}=\frac{dP'}{A}$$

therefore

$$K_0A'=A'\left(1+\frac{dV_0}{A'}+\frac{dP}{A'}\right)=A'+dV_0+dP'$$

and

$$K_0A'+M'=A'+dV_0+dP'+d\varpi'+dW_x'$$

which is the expression for the adjustment range, and, when corrected for the site increment will give the range-table range corresponding to the corrected quadrant angle of elevation.

REMARKS.

If it is required to make several adjustments on the same target, with the same lot of ammunition, the three elements indicated will be concordant to a degree of approximation depending on the error made in evaluating the atmospheric corrections. If for one of the adjustments the results are plainly discordant, it must be concluded from this fact either that the lot has suffered some abnormal change, which is

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rare, or that assumptions regarding atmospheric conditions used as the basis of the computations are especially faulty. The conclusion last stated is the more plausible. When an anomaly has been observed the thing to do is to ask for confirmation of the meteorologic bulletins concerned and to begin again, if necessary, the computation of the corrections.

It is understood that all adjustments here considered should include a verification fire of at least 12 rounds. If we are unable to draw a conclusion from observing two or three rounds, it is even more impossible to deduce a coefficient from them.

In the proceeding just indicated successive firings will overlap one another. By carefully noting, for the region and for each target, the quantities D_0 and K_0 and the theoretical deflection, we shall have a series of elements of which we take the mean for each target. This mean will serve as a basis for new calculations of initial data. If a result differs too much from this mean the cause of the anomaly should be sought. Often the result may be corrected by a better knowledge of atmospheric conditions. All this supposes that ammunition from the same lot has been used. If the lot has been changed the coefficients of adjustment and the adjustment ranges will have other values.

The expressions "given lot of powder," "same lot of powder," used again and again in the explanation given above, mean a lot of powder giving the same initial velocity with projectiles of the same weight. In reality this initial velocity is also a function of the temperature, but under conditions that are rather ill defined, as we have already seen (p. 119). On the other hand, for all practical purposes it is very evident that the firings which we wish to compare with one another are those which have been executed in the same period and with charges coming from ammunition depots in which the powder is kept under almost constant temperature. In practice it is therefore permissible to neglect to a certain extent variations in the initial velocity depending on temperature and to consider in the long run only the "lot of powder."

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SUMMARY.

The two following points especially should be remembered:

1. The most certain corrections in range that can be applied on the field of battle are those pertaining to variation in the weight of the projectiles and of a liter of air (dP and $d\tilde{\omega}$). The correction due to wind will often be uncertain by reason of the variation of W_x with the altitude. Finally, the corrections due to the initial velocity will be still more uncertain.

2. In practice, for a series of firings made within the same period and with ammunition of the same lot (projectiles of the same weight and the same lot of powder), allowance should generally be made only for the correction for the weight of a liter of air and for the wind. The range-table range corresponding to the corrected quadrant angle of elevation, or the coefficient of adjustment K_0, defined above, should be used in resuming fire on the same target or in effecting a transfer of the fire.

A series of firings carried out by a command of heavy artillery with the 155-millimeter gun, the 100-millimeter rapid-fire gun, and the 280-millimeter mortar gave the following results, which are set forth in a note of the Second Army:

With the same lot of powder, and for projectiles whose weights are nearly equal:

1. The corrected adjustment ranges (D—M) on the same target show from day to day differences that are sensibly less, not only in the corresponding brackets but also in the probable error.

2. The coefficient of adjustment $\left(K_0=\frac{D-M}{A}\right)$ for different targets, located according to the conditions for the transfer of fire (ratio of ranges between three-fourths and four-thirds, angular difference in deflection not exceeding 200 decigrads), remains almost constant. We deduce from these facts the following consequences:

(a) If fire has been adjusted on a certain target, either for the purpose of firing on that target some other day or for firing

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on another target located with reference to the first under the conditions required for the transfer of fire, trial fire is unnecessary. It is enough to verify the quadrant of elevation, then to pass on to the verification fire, and then to fire for effect. It is evident that this rule applies only if the behavior of the guns is the same; otherwise account must be taken, for each gun, of a corrected individual coefficient.

(*b*) If the fire can not be observed the use of the corrected coefficient of adjustment K_0 will permit immediate fire on a zone with one-half bracket over and one-half bracket short, which will include the target, the bracket including 4 possible errors.

(*c*) If during fire for effect following immediately fire for adjustment the meteorologic conditions change and are announced by a fresh bulletin, there should be no hesitation in interrupting the fire for effect and in correcting the range by the difference in the meteorologic corrections. Having done this, verify the angle and execute a new verification fire with the new data before resuming the fire for effect.

(*d*) The elevation called "elevation of the day" [hausse du jour] is a factor that has no value unless the meteorologic conditions are unchanged. The important element is the "elevation of the moment," or, rather, the atmospheric condition of the moment.

EXAMPLES OF THE CALCULATION OF THE INITIAL FIRING DATA DIRECTLY ON THE TARGET; CALCULATION OF K_0.

The following examples of computation show how to determine the initial elements of fire under the conditions already considered as well as the coefficients of adjustment, and how to use the elements resulting from the adjustments in calculating the coefficients of adjustment. For the reasons previously stated, no account has been taken in these calculations of the corrections for initial velocity (temperature of the powder), but it is possible that precise directions on this point may be formulated in

the forthcoming range tables and that these corrections may be definitely prescribed. The following examples should not, therefore, be considered in any way models of the calculations that should be made in the preparation for fire. They are given only by way of illustration. This remark applies equally to the examples given on pages 145–149.

EXAMPLE 1. FIRE OF THE 75-MILLIMETER GUN.

Data common to the three cases considered: The fire is executed with a 75-millimeter gun, with explosive shells fitted with fuse I; initial velocity, 550 meters. On the plotting board the angle α (aiming point–gun–target) = 83 mils.

The target is to the left of the aiming line and has an altitude 35 meters greater than that of the battery. The topographic range is 5,000 meters, lot 121. The site is $+\frac{35}{5.0} = 7$ mils. Site zero has been laid off at the gun.

Summary provisional range tables for explosive shells fitted with fuses I and IA and fired with a velocity of 550 meters, August 12, 1916, are used [Tables de tir sommaires et provisoires des obus explosifs armés de fusées I et IA et tirés à la vitesse de 550^{m}, 12 août, 1916].

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Computation of firing data for 75-millimeter gun aimed directly on the target.

Conditions of the moment.

	First case.	Second case.	Third case.
Temperature (t) Pressure (H) Velocity (V_0) (W_x) Components Direction (δ_0) (W_y) adopted.	Data unknown.	$t = -5$ $H = 770$ $V_0 = 8$ $\delta_0 = 35$ $W_x = 6$ [a] $W_y = 6$	$t = +6$ $H = +761$ $V_0 =$ zero δ_0

Computation of corrections in range.

Topographic range A		*Meters.* 5,000			*Meters.* 5,000		*Meters.* 5,000
Correction for the variation in the weight of a liter of air ($d\bar{w}$)	Argument A	These corrections not made.		(128) (− 1.61) = −206 [b]		(60) (−1.61) = −97	
Correction for wind (dW_x)	Δ			6× (− 14.9) = − 89	+295	0	+97
Δ		5,000		−295	5,295	−97	5,097
Correction for site (S) (Argument Δ)		+100		+7 mils for 5,295	+85	+7 mils for 5,100	+ 92
Range		5,100			5,380		5,189
Corresponding quadrant setting		Site+70	4,450	Site+70	$d = 4,825$	Site+70	4,575

For footnotes see page 137.

Computation of firing data for 75-millimeter gun aimed directly on the target—Continued.

Computation of corrections in range—Continued.

	First case.	Second case.	Third case.
Quadrant setting obtained by adjustment	Site+70 *Meters.* 4,675	Site+70 *Meters.* 4,875	Site+70 *Meters.* 4,625
Range-table range corresponding to the above for zero angle of site		5,417	5,240
Atmospheric corrections with sign changed(−M)		−295	− 97
Range-table range reduced to normal conditions (P−M)		5,122	5,143
Range-table range reduced to normal conditions (P−M)		5,122	
Correction for site with sign changed(−S)		− 85	
Theoretical range from adjustment (D_0)		5,037	
$K_0=\frac{D_0}{A}$		$K_0=1+\frac{37}{5000}=1.007$	$K_0=1+\frac{43}{5000}=1.009$

Computation of elements of direction.

Deflection	*Mils.* + 83	*Mils.* + 83	*Mils.* + 83
Drift	+ 9	+ 9	+ 9
Correction for wind		(15×0.6)= +9	+ 9	+ 0
Corrected deflection	+ 92	+101	+ 92
Main scale (M. S.) azimuth micrometer (A. M.)	M. S. zero A. M. 192	*Mils.* *Mils.* M. S. 2 A. M. 1	*Mils.* M. S. zero A. M. 192

Main scale (M. S.), azimuth micrometer (A. M.)

Elements obtained.....	M. S. zero A. M. 199	M. S. 2 A. M. 5	M. S. zero A. M. 195
Corrections with changed sign.....	.....	−18	− 9
Deflection reduced to normal conditions.....	.....	M. S. zero A. M. 187	M. S. zero A. M. 186

[a] The maximum ordinate a is 394 meters, three-fourths of which is 291 meters. The soundings are the following:

200 meters . . . $\delta_o = 4$ $V_o = 7$
300 meters . . . $\delta_o = 5$ $V_o = 8$
400 meters . . . $\delta_o = 6$ $V_o = 10$

The force and velocity are assumed to be the force and velocity at 300 meters, by the method given.

[b] The corrections, with their signs, when computed from the appendix to the range tables of Feb. 2, 1916 (l'Annexe aux tables de tir du 2 février 1916), are:

	Meters.
(10. 5) (19) =	+ 200
$\frac{140}{10} \times 6 =$	+ 84
	+284 instead of +295.

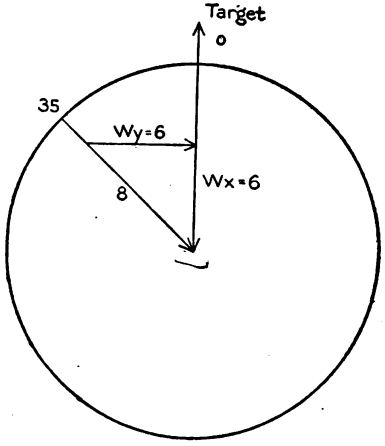

FIGURE 45.—Graphic method of determining the components of the wind.

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EXAMPLE 2. FIRE OF THE 155-MILLIMETER HOWITZER.

Data common to the examples considered: The piece fired is a 155-millimeter howitzer with long shells and charge 0, lot 17.

The angular difference in deflection between the target and the aiming line is 52 decigrads; the target is to the right of the aiming line. The topographic range measured on the board is 4,700 meters. The altitude of the target is 43 meters greater than that of the battery.

Practical range tables for the 155-millimeter howitzers, approved November 4, 1905, and the appendix to the range tables of February 2, 1916, are used [Tables pratiques de tir du canon de 155 millimètres court, approuvées le 4 novembre 1905; annexe aux tables de tir du 2 février 1916].

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Computation of firing data of 155-millimeter howitzer aimed directly on the target.

Conditions of the moment.

	First case.	Second case.	Third case.
Barometric pressure (H)	Unknown.	768	750
Temperature (t)		0	8
Assumed wind, direction		+8.2	+2.5
Assumed wind, velocity		6	12
Longitudinal component (W_x)		16	6
Transverse component (W_y)		15 (See fig. 46, p. 141.)	5 (See fig. 47, p. 141.)
		5	4

Computation of corrections in range.

	First case.	Second case.	Third case.
	Meters.	Meters.	Meters.
Topographic range A	4,700	4,700	4,700
Correction for t and H		(+8.2) (8.6) = +70	(+2.5) (8.6) = +21
Correction for wind		(+8.1) 15 = 121 +191	(+8.1) 5 = +41 +62
		+191	+62
Corrected range	4,700	4,891	4,762
Corresponding elevation	° ′ 22 35	° ′ 24 4	° ′ 23 3
Angle of site	+31′ = (0.73×43)	+31′ = (0.73×43)	+31′ = (0.73×43)
Supplementary correction for site	+ 7	+ 8	+ 7
Total correction for site	+38′ + 38	+39′ + 39	+38′ + 38
Computed quadrant elevation	23 13	24 43	23 41

Computation of firing data of 155-millimeter howitzer aimed directly on the target—Continued.

Computation of corrections in range—Continued.

	First case.	Second case.	Third case.
Adjustment quadrant elevation	° ′ 24 52	° ′ 24 53	° ′ 23 48
Correction for site with changed sign	−38	−39	−38
Adjustment elevation	24 14	24 14	23 10
D=corresponding range-table range	*Meters.* 4,912	*Meters.* 4,912	*Meters.* 4,776
$K=\frac{D}{A}$	$K=1+\frac{212}{4700}=1.045$	$K=1+\frac{212}{4700}=1.045$	$K=1+\frac{76}{4700}=1.016$
Corrections for density of atmosphere and for wind with changed sign		−191	−62
D_0=theoretical adjustment range reduced to zero corrections		4,721	4,714
$K_0=\frac{D_0}{A}$		$K_0=1+\frac{21}{4700}=1.005$	$K_0=1+\frac{14}{4700}=1.003$
Elevation corresponding to D_0			

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Angle (aiming point–gun–target)		*Mils.* +52		*Mils.* +52	*Mils.* +52
Drift		− 6		− 6	− 6
Correction for wind			(−4.2) 0.5	− 2	(+4.2) 0.4 + 2
Deflection		+46		+44	+48
Adjustment deflection		+48		+48	+51
Corrections with changed sign				+ 8	+ 4
Theoretical deflection				+56	+55

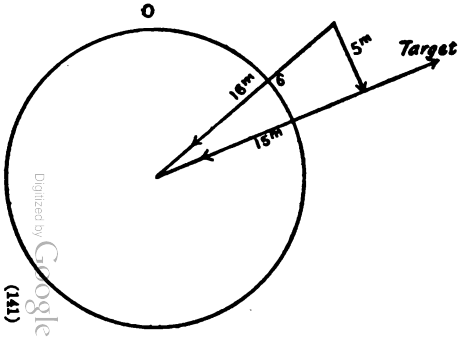

FIGURE 46.—Graphic method of determining the components of the wind.

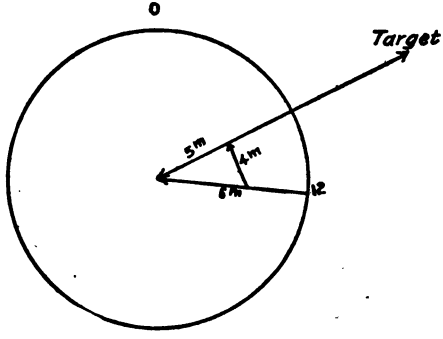

FIGURE 47.—Graphic method of determining the components of the wind.

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EXAMPLE 3. FIRE OF THE 155-MILLIMETER GUN.

Data common to the examples considered: The gun fired is a 155-millimeter gun, model 1877–1914, with elongated shells, model 1914 and charges 000. Shell of normal weight, lot 95.

The angular difference in deflection between the target and the aiming line is 95 mils; the target is to the left of the aiming point. The topographic range measured on the board is 9,100 meters. The altitude of the target is 200 meters less than that of the gun. The angle of site is therefore —22 mils.

Range tables for the 155-millimeter gun, model 1877 and model 1877–1914 of March 27, 1916, are used [Tables de tir des canons de 155 millimetres long modèle 1877 et modèle 1877–1914, du 27 mars 1916].

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Computation of firing data of 155-millimeter gun aimed directly on the target.

Conditions of the moment.

	First case.	Second case.	Third case.
Barometric pressure (H) Temperature (t) Assumed wind, direction Assumed wind, velocity Longitudinal component (W_x) Transverse component (W_y)	Unknown.	H=770 t=−5 } +128 δ=35 [a] V_0=8 Wx=6 Wy=6	H=761 t =+6 } +60 δ_0 V_0 zero

Computation of corrections in range. [b]

	First case.		Second case.		Third case.	
		Meters.		*Meters.*		*Meters.*
Topographic range A		9,100		9,100		9,100
Correction for t and H		0	(+128) (−2.56)=−328 (6) (−25.2)=−151	+479	(+60) (−2.56)=−151 0	+151
Corrected range		9,100	−479	9,579	−151	9,251
Corresponding elevation	c 423		c 473		c 438	
	Mils.		*Mils.*		*Mils.*	
Angle of site	−22		−22		−22	
Supplementary correction for site	− 4		− 5		− 5	
Total correction for site	−26		−27		−27	
Computed elevation	c 423		c 473		c 438	

[a] The soundings used have led to the adoption of V_0=8 and δ_0=35. Direction of fire is to the north.

[b] In the 155-millimeter gun, model 1877–1914, the site is set off in mils on the sighting apparatus, so that there is no need of touching the elevating gear. The elevation is expressed in twentieths. The supplementary correction for site is computed with the corrected distance as a basis.

[c] Twentieths of a degree.

Computation of firing data of 155-millimeter gun aimed directly on the target—Continued.

Computation of corrections in range—Continued.

	First case.	Second case.	Third case.
Adjustment quadrant elevation	[a] 430	[a] 490	[a] 456
Correction for site with sign changed.			
Adjustment elevation	[a] 430	[a] 490	[a] 456
D=corresponding range table	*Meters.* 9,170	*Meters.* 9,730	*Meters.* 9,430
$K=\frac{D}{A}$	$K=1+\frac{70}{9100}=1.008$	$K=1+\frac{630}{9100}=1.069$	$K=1+\frac{330}{9100}=1.036$
Algebraic sum of the corrections for atmospheric density and for wind with sign changed	Unknown.	−479	−151
D_0=theoretical adjustment range reduced to zero corrections	Can not be found.	9,251	9,279
$K_0=\frac{D_0}{A}$	Can not be found.	$K_0=1+\frac{151}{9100}=1.017$	$K_0=1+\frac{179}{9100}=1.020$
Elevation corresponding to D_0	Can not be found.	[a] 438	[a] 441

Computation of elements of direction.[b]

	First case.	Second case.	Third case.
Angle aiming point-gun-target	*Mils.* + 95	*Mils.* + 95	*Mils.* + 95
Drift	+20{+ 20	$(1.5\times6)=9\begin{cases}+22\\31\end{cases}$ {+ 22	+ 24
Correction for wind	0	+ 9	0
Deflection	+115	+126	+119
Adjustment deflection	125	128	123
Corrections with changed sign	− 20	− 31	− 24
Theoretical deflection	+105	+ 97	+ 99

[a] Twentieths of a degree.

[b] The aiming circle is divided into 6,400 parts, numbered in clockwise direction.

EXAMPLES OF CALCULATION OF THE FIRING DATA FOR TRANSFER OF FIRE OR BY THE USE OF A REFERENCE TARGET.

After the firing treated in the above computations has been executed the next step is to provide for fire on targets close to those just considered which may be regarded as auxiliary or reference targets.

Suppose that the targets already considered have been fired on for about an hour. A coefficient K_o has been found that does not differ from the figures already obtained. Other firing has not brought to light any irregularities in other values of K_o corresponding to other distances. The atmospheric conditions are therefore well known. Start with the value K_o corresponding to the range and compute the initial data in the manner shown below.

EXAMPLE 1: FIRE OF THE 75-MILLIMETER GUN.

Firing with a 75-millimeter gun on the first target has led to the adoption of a coefficient of adjustment 1.009, lot 121, fuse I. It is desired to fire with the same ammunition on another target at range A=5,300 meters and in a direction 130 mils to the left of the aiming line. The angular difference in deflection between the first and second targets has been found to be 47 mils. The angle between the first target and the aiming point, reduced to zero corrections, is 83 mils (47+83=130). The angle of site is +8 mils. As the new target is not very far from the old one, and as further fire on the old one has given us a value of K_o practically equal to 1.009, we prepare for fire on the new target in the following manner:

$$\left.\begin{matrix} H=760 \\ t=10 \end{matrix}\right\} d\varpi = +40$$

$$\left.\begin{matrix} \delta^0 = 0 \\ V^0 = 10 \end{matrix}\right\}$$ The gun is aimed toward the north. $$\left\{\begin{matrix} W_y = 10 \\ W_x = 0 \end{matrix}\right.$$

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Computation of firing data for 75-millimeter gun by transfer of fire or by use of a reference target.

Range.

		Meters.
Topographic range A		5,300
Corrections for t and H	(40) (−1.73)= − 69	
Correction for wind	(10) (165)= −165	
Total of the corrections	−234	+ 234
K_0A	(1.009) 5,300=	5,349
Corrected range Δ		5,583
Correction for site	+ 8 mils for 5,583	+ 90
Range		5,673
Corresponding quadrant setting	Site+70	5,250
Quandant setting obtained by adjustment	Site+70	5,300
Range-table range corresponding to the above for zero angle of site		5,700
Corrections for density of atmosphere with changed sign (−M)		− 234
Range reduced to normal conditions		5,466
Range reduced to normal conditions		5,466
Correction for site with changed sign		− 90
Theoretical adjustment range reduced to zero corrections (D_0)		5,376
$K_0 = \frac{D_0}{A}$	$1+\frac{76}{5,300}=1,014$	

Direction.

		Mils.	*Mils.*
Deflection	(M.S. 0, A.M. 187+47)	M.S. 2	A.M. 34
Drift			11
Correction for wind			0
Sight readings		M.S. 2	A.M. 45
Readings obtained by adjustment		M.S. 2	A.M. 47
Corrections with changed sign			−11
Deflection reduced to normal conditions		M.S. 2	A.M. 36

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EXAMPLE 2: FIRE OF THE 155-MILLIMETER HOWITZER.

A certain amount of firing has just been done with a 155-millimeter howitzer and has merely confirmed the values of the coefficient K_0 previously found. The atmospheric conditions are therefore well known. It is desired to fire on a new target at 5,000 meters range and 75 decigrads to the right of the aiming line. Its altitude is 70 meters above that of the gun. Start from the value $K_0=1.004$, previously found for the former target, which is a short distance away from the new target. The lot used was No. 17, charge 0, long shell. As adjustment on a new target is possible, the new value of K_0 will be deduced. (See fig. 48.)

$H=750$
$t=0$ } (+5.7)
$\delta_0=37$
$V_0=12$
$W_x=2$
$W_y=12$

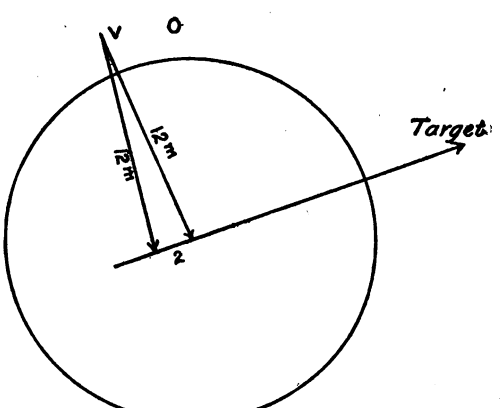

FIGURE 48.—Graphic method of determining the components of the wind.

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Computation of firing data for 155-millimeter howitzer by transfer of fire or by use of a reference target.

Range.

						Meters.
Topographic range A						5,000
Correction for t and H } Argument A	(5.7) (9.5) =		+54			
Correction for wind... }	(−2) (9.0) =		−18			
Total of the corrections M			+36			+36
K_0A	(1.004) 5,000					5,020
Corrected range Δ						5,056
				°	′	
Corresponding elevation				25	27	
		°	′			
Angle of site	(0′.69) (70) =		48			
Supplementary correction for site			15			
Total correction for site		+1	3	1	3	
Computed quadrant elevation				26	30	
Adjustment quadrant elevation				26	45	
Correction for site with changed sign				−1	3	
Adjustment elevation				25	42	
D = adjustment range-table range						5,084
$K=\frac{D}{A}$	$K=1+\frac{84}{5,000}=1.017$					
Sum of the corrections for density of atmosphere and for wind with changed sign						−36
D_0 = theoretical adjustment range reduced to zero corrections						5,048
$K_0=\frac{D_0}{A}$	$K_0=1+\frac{48}{5,000}=1.010$					
Elevation corresponding to D_0				25°	23′	

EXAMPLE 3: FIRE OF THE 155-MILLIMETER GUN.

A 155-millimeter gun, long model of 1877–1914, has been fired on its first target, and the fire has led to the adoption of 1.018 as the coefficient of adjustment for lot 95, charge 000. It is desired to fire on another target at a range of A=8,600 meters and 155 mils to the left of the aiming line. The angle of site is 20 mils. Adjustment is therefore possible on the new target. As this new target is not very far from the preceding one the

coefficient of adjustment just determined will be used to obtain the initial data for the new fire. Adjustment will be made directly on the new target, without going through the process of adjusting on the old target, which nevertheless has served as an auxiliary target, for it has furnished the value of K_0.

$$\left.\begin{matrix} H=760 \\ t=\ 10 \end{matrix}\right\} d\varpi = +40$$

$$\left.\begin{matrix} \delta_0 = 0 \\ V_0 = 10 \end{matrix}\right\}$$ The gun is aimed toward the north. $$\left\{\begin{matrix} W_x = 10 \\ W_y = 0 \end{matrix}\right.$$

Computation of firing data for 155-millimeter gun by transfer of fire or by use of a reference target.

Range.

			Meters.
Topographic range A			8,600
Correction for t and H / Correction for wind / Argument A	(40) (−2.39) =	− 96	
	(10) (−23.1) =	−231	
Total of the corrections M		−327	+327
K_0A	K_0 = 1.018		8,755
Corrected range Δ			9,082
	Mils.		
Corresponding elevation (in twentieths)		a 422	
Angle of site	−20		
Supplementary correction for site, Argument Δ	− 4		
Total correction for site	−24		
Computed quadrant elevation		a 422	

	Mils.		
Adjustment quadrant elevation		a 426	
Correction for site with changed sign	+24		
Adjustment elevation		a 426	
D = adjustment range-table range			9,130
$K = \frac{D}{A}$	$1+\frac{530}{8600} = 1.062$		
Sum of the corrections for density of atmosphere and for wind with changed sign			−327
D_0 = theoretical adjustment range reduced to zero corrections			8,808
$K_0 = \frac{D_0}{A}$	$K_0 = 1+\frac{203}{8600} = 1.024$		
Elevation corresponding to D_0		a396	

a Twentieths of a degree.

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PRACTICAL COMPUTATIONS BY THE BATTERIES.

The examples already given relate to the data for a single gun. In practice the computation must be made for all guns. Forms of computation for this purpose have been prepared in several quarters. The model proposed by the Center of Studies for Heavy Artillery [Centre d'études d'artillerie du groupement de l'artillerie lourde] is given below only as a suggestion. It separates clearly the data from the operations or calculations to be made. It shows—

1. The firing data to be obtained—data relating to the battery, to the target, to the soundings, to the components of the wind, and the barothermometric coefficient.
2. The computation of the corrections.
3. The computation of the angles of elevation and the directions of fire.
4. The derived fire for adjustment.

The expressions used, some of which are new (barothermometric coefficient, aerologic correction, corrected range, initial angle of elevation, deflection range, and deduced deflection), have the advantage of defining briefly all elements that must be considered.

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Suggested model for computation by the batteries.

Elements.

Battery:	Target:	Wind:	Wind:
x.....	x.....	Velocity.	Longit.... ....
y.....	y.....	Direction	Transv.... ....
A.....	A.....		
Type of shell..	Topographic	Temperature.	Barotherm.
Lot of powder.	range (P)	Barom. press.	coefficient... ....
	Site (S).....	K_0 preceding [a]	

Corrections.		Place for computations.
In range (meters).	In direction (decigrads).	
Barotherm....	Transverse	
Longitudinal wind.....	wind.....	
Aerologic correction(p)		

Angle of elevation.		Direction of fire.[b]				
			Gun 4.	Gun 3.	Gun 2.	Gun 1.
Topographic range (P)...	.....	Surveillance (S).....	.....	.....	.....	.....
Corrected range ($P_{\times}K_0$)..	.....	Displacement of the sheaf.....	.....	.....	.....	.....
Aerologic correction (r).	.....	Convergence.....	.....	.....	.....	.....
Total of the last two [c].	.....	Drift.....	.....	.....	.....	.....
Corresponding elevation.	.....	Apparent directions (D).....	.....	.....	.....	.....
Site (S).....	.....	Wind.....	.....	.....	.....	.....
Initial quadrant elevation.....	.....	Corrections from previous adjustments (δ) [d].....	.....	.....	.....	.....
		Deflection.....	.....	.....	.....	.....

[a] If no previous fire made with the lot of powder used is available, take $K_0 = 1$.
[b] All computations of the direction are made on the jacket goniometer.
[c] If the aiming is done with the sight scale (75-millimeter gun) take this range as the point of departure and strike out what is below.
[d] If the target is fired on for the first time, take $\delta = 0$.

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Suggested model for computation by the batteries—Continued.

Derived fire for adjustment.

			Gun 4.	Gun 3.	Gun 2.	Gun 1.
Adjustment quadrant elevation		Directions from adjustment				
Site reversed (−S)		Wind reversed				
Sum of the two		Directions cleared of corrections (D′)				
Corresponding range-table range [a]						
Aerologic correction reversed (−p)						
Range cleared of corrections (P′)						
Coefficient of adjustment $\left(K_0=\frac{P'}{P}\right)$		Adjustment corrections ($\delta=D'-D$)				

[a] If the aiming is done with the sight scale (75-millimeter gun) set down the range of adjustment in this place and strike out what is above.

RECORDS OF THE FIRE.

The records of the fire should always contain the results of the topographic operations that have been performed. They should show the coordinates of the directing gun and its altitude and the direction of the aiming point. In entering its coordinates make sure that they actually locate this aiming point on the line that passes through the gun and that was obtained by topographic methods. Give the directions of surveillance which have been determined from the fire. Draw in very accurately the total field of fire. This information is necessary in order to permit arrangements to be made for concentrations of fire. Data about minimum elevations and zones in the dead angles are almost always obtained by means of the battle map. Study this matter closely.

Note that for heavy artillery the definition of the aiming point should include the line gun–aiming point. The line may be defined by the angle which it makes with the axes of the system of squares, but this is not a very practicable method

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to use on plane-table sheets; and it is better, in this case, to give the coordinates of a point on the desired line, taken near the edge of the sheet on one of the sides of the system of squares. This point is placed as far as possible from the gun,

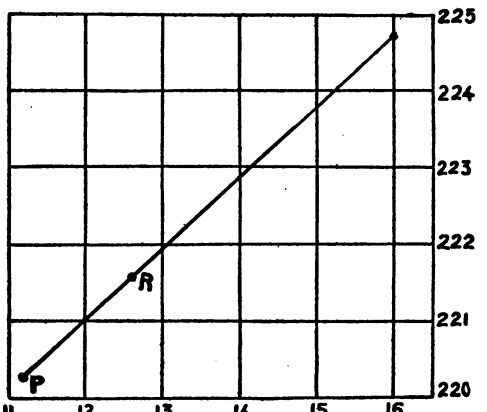

FIGURE 49.—Graphic record of fire.

and its choice depends on that condition only. It may perfectly well be on the side opposite the aiming point with regard to the directing gun.

For example (see fig. 49), for heavy artillery, the definition may be given in the following way:

Principal aiming point
- Defined by steeple at N.
- The aiming line passes through the gun and through $x_3=16.000$, $y_3=224.890$.
- Coordinates
  - $x_2=12.510$.
  - $y_2=221.535$.

As the coordinates of the gun are $x_1=11.210$, $y_1=220.285$, we should have—

$$\frac{x_3-x_1}{y_3-y_1}=\frac{x_2-x_1}{y_2-y_1}$$

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or in this case—

$$\frac{12.510-11.210}{221.535-220.285}=\frac{16.000-11.210}{224.890-220.285}=1.040$$

For field artillery there are tables which show the temperature and pressure. The corrected data should be reduced to normal conditions. There are also tables which give the value of the elements reduced to normal conditions. Examples of recapitulation for the target of the elements reduced to normal conditions after each fire for adjustment have been published, assuming the use of a particular lot of projectiles.

For heavy artillery the use of the record requires no remark. It is merely necessary to keep together the results of the firing, reduced to normal conditions, made on the same target.

Within the battalion, the fact that the major gives orders for the adjustments made by airplane and supervises them makes it necessary that the batteries should keep a record of the data of fire already adjusted by airplane and reduced to normal conditions. The orientation officer or the "wireless" officer should prepare a table of them. It will then be easy to decide when one or another adjustment is to be resumed.

It may further be observed that often, when a battery is relieved, the necessary data are not collected. For lack of entries made in the record books at the usual time a considerable amount of work done by the units previously on the spot is lost. The new arrivals are obliged to begin the adjustment over again. A few entries and a little orderliness and care will avoid the necessity for much useless fire and will enable one to strive intelligently for a preparation for fire that may often be very complete. Battery commanders have, furthermore, a real interest in preserving results that are conducive to rapid adjustments, for these results enable them to connect one set of fire with another. It is, moreover, imperatively necessary to preserve these results, for they afford one of the best means of avoiding waste of ammunition.

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Site.
Mils (6400)
.....do.....
.....do.....
Degrees and
Degrees and
.....do.....
.....do.....
.....do.....
.....do.....
.....do.....
.....do.....
.....do.....
.....do.....
.....do.....
Mils (6000)
.....do.....
Mils (6400)
.....do.....
.....do.....
Mils (6000)
.....do.....
Mils (6400)
.....
.....

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CHAPTER VI.

ERRORS IN MAP FIRING.

GENERAL CONSIDERATIONS.

The errors resulting from the use of different methods and instruments in the topographic surveys made by batteries and in the location of the targets plotted on the maps affect the data used for fire.

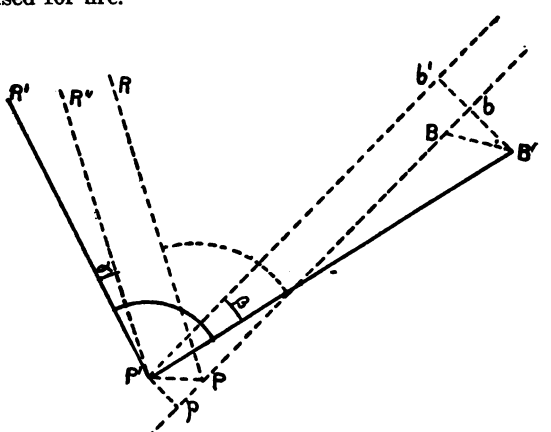

FIGURE 50.—Nature of errors in firing data due to inaccuracy of topographic location.

Suppose that the gun and aiming line are only approximately located and that the target is not accurately located either on the topographic map or on the battle map. What are the errors due to the use of these inaccurate data? (See fig. 50.) Let P and B be the exact positions of the gun and of the target, PR the

exact direction of the aiming line. Let P′ and B′ be the assumed positions of the gun and of the target, P′R′ the assumed direction of the aiming line—elements that have been determined and transferred to the plane table. Let the lines P′R″ and P′b' be drawn through P′ parallel, respectively, to PR and PB. The topographic range, which will be used as a basis for calculating the range, will be P′B′ instead of PB. Let P′p and B′b be perpendicular to PB; we have very nearly

$$P'B'=pP+PB+Bb.$$

Now, in the two right triangles PP′p and BB′b, pP and Bb (sides of the right angle) are always less, respectively, than P′P and B′B (the hypotenuses of these triangles). The maximum error with which P′B′ will be affected will therefore be BB′+PP′. Only this maximum error is of interest, for it is impossible to know the exact position of the gun and of the target and to deduce the relative error from the errors of each of these points.

Thus the maximum error that may occur in the range as a result of the inaccuracy of these points is equal to the sum of the errors that may occur in the positions of the directing gun and of the target.

In laying the directing gun the angle R′P′B′ will be used instead of the angle RPB.

The error made in direction will then be R′P′R″+b'P′B′. Now R′P′R″=a=error in the aiming line, and—

$$b'P'B'=\frac{B'b'}{P'B'}=\frac{B'b+bb'}{P'B'}=\frac{B'b+P'p}{P'B'}=\beta$$

expressed in mils if P′B′ is expressed in kilometers.

By observing, as before, that B′b and P′p are always less than PP′ and BB′, it is seen that the maximum error to be feared in the direction of fire is, when expressed in mils, equal to—

$$a+\frac{BB'+PP'}{P'B'}$$

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α expressed in mils, P'B' in kilometers, and BB' and PP' in meters.

As has been said with regard to the range, only the maximum error in direction is considered.

These principles having been established, the two following problems may be proposed and solved:

1. What are the errors in range and in direction which may result from the use of the regular map or of a battle map?

2. It is desired to fire with a given precision and given maximum errors due to inaccuracy of maps and battle maps: What instruments and methods should be used to obtain the position of the battery and the orientation of the aiming line or aiming point?

ACCURACY OF ARTILLERY SURVEYS.

Certain data derived from experience and from the study of instrumental errors are indispensable in solving the problems given above.

On the battle maps and the topographic maps the points of the general control used for topographic surveys or in preparation for fire are exact within the limits of plotting. The plotting error is the error arising from inaccuracies in transferring; a transfer made by pencil by an average draftsman may be in error 0.2 millimeter.

The maximum errors to be feared for the ordinary points of the planimetric details, except in case of a blunder, are—

For the regular battle maps of a time of peace, on a scale of 1:10,000, 5 meters; on a scale of 1:20,000, 10 meters.

For the battle maps on scales of 1:20,000 and 1:10,000, made during military operations, different degrees of accuracy, according to the region and sources used, but in general of the same order of magnitude as the foregoing.

For maps on a scale of 1:50,000, enlarged from maps on a scale of 1:80,000, or on the 1:80,000 map itself, 100 meters.

Directions are determined with maximum errors of 0.5 mil by theodolites of various models and astronomical observations;

1 mil by the theodolites used in certain batteries of heavy artillery, the work being based on the general control; 2 mils by the compass theodolite, based on points of the general control; 3 mils by the compass goniometer set for declination, use being made of the general control; 5 mils by the plane table and compass, based on points of the general control; 20 mils by the goniometer, compass theodolite, or plane table and compass, with the magnetic declinations given by the tables.

Distances are measured with a chain or with the stadia up to distances of 100 meters with an error of within one in a thousand. If distances are greater than this, or if there are reductions to the horizontal, the accuracy decreases and may fall to 1 in 500 or even to 1 in 200.

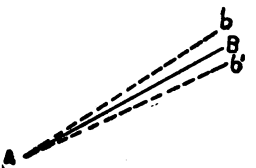

FIGURE 51.—Error in sighting.

The use of the general control to locate points by the three-point method, by intersection or resection, enables us to obtain these points within 10 meters at most.

Traversing gives the points with an error depending on the number of consecutive operations. If n is this number and if a is the error to be feared in the position of a station determined by a course of average length, the resulting error in the last point will be $a\sqrt{n}$.

At a station A (fig. 51) a line of sight drawn to a point B will lie within an angle bAb' such that $bAB=BAb'$=error in direction=5 mils at most. Along this line the point is plotted within the limits of graphic error and the error in measuring the distance. In practice, the error will amount to 0.3 millimeter for

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an average person, whatever may be the scale—that is, the scales in use from 1:5,000 up to 1:20,000.

Another error comes in if the plane table is oriented only by compass with an error in azimuth β (fig. 52). This error displaces the true point B to B′ by an amount equal to $BB'=\beta\times AB$. If $\beta=20$ mils and AB=1,500 meters, $BB'=\frac{20\times1,500}{1,000}=30$

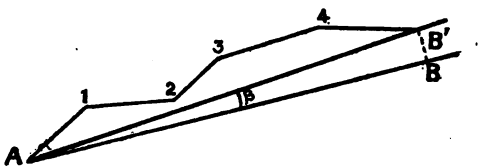

FIGURE 52.—Error of azimuth in a traverse.

meters. This is the sort of thing that may happen if a tabular magnetic declination is used that does not agree with the actual local declination.

The value of β may be considerable, as we have already seen. If, for example, we orient ourselves at a station that is 50 meters in error by sighting on a control point only 500 meters distant and 50 meters in error, $\beta=100$ mils.

VARIOUS EXAMPLES.

Let us take some examples of the two problems stated above, under "General considerations":

FIRST PROBLEM.

Example 1.—The orientation officer for a battery of heavy artillery has determined a point A by the three-point method on the general control. He has made a traverse of four stations with plane table and compass from A to the gun P, the plane table having been oriented at A.

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The maximum error in position of the gun arises from the following errors:

	Meters.
Error in the position of A	10
Error in the traverse $0.3 \times \sqrt{4}=0.6$ millimeter, or on a scale of 1:10,000	6
	16

The battle map used gives within 10 meters the position of a target situated 4,000 meters from the gun. The maximum error in the distance used as a basis for computing the range will be 10+16=26 meters.

The maximum error in the datum used as a basis in the calculation of the deflection will be 11 mils, namely, 5 mils error in orientation by plane table and compass at A (see above)$+\frac{26}{4000}$=6 mils.

Example 2.—The position of a battery of 75-millimeter guns has been located by a survey from a point in the planimetric detail (a hut). A traverse 1 kilometer in length has been made in order to reach the directing gun. This traverse closes on another point of the planimetric detail; it was made by plane table and compass on a scale of 1:10,000. The error of closure was 2 millimeters, which was adjusted. The aiming line was determined by the battery with the compass goniometer, the declination having been previously obtained at a control point. The line was plotted with a celluloid protractor.

The battle map on the scale of 1:20,000, used in determining the points, may, according to the information at hand, be subject to errors of 20 meters in the position of the points. The error which may occur in a traverse of 20 courses is 0.3 millimeter $\times \sqrt{20}$=13 meters on a scale of 1:10,000. Twenty meters was actually found. This is not excessive, for the relative position of the initial and terminal points is subject to an error greater than the difference of 7 meters found (20 − 13 = 7).

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It may be said that the error in the position of the directing gun is known within at least 10 meters after the adjustment has been made with reference to the initial and terminal points.

The error in position of the gun is then at most 30 meters, namely, 20 meters arising from the error in the initial point and 10 meters arising from the topographic determinations.

The aiming line is determined by the compass goniometer under the assumed conditions within 3 mils. The plotting of this line on the plane table may involve a new error of 2 mils, or a total of 5 mils. The position of the target itself is not determined within 20 meters. It is supposed to be 4,500 meters away.

The error in the direction of fire may be 16 mils, namely, 5 mils arising from the use of the compass goniometer, plus 11 mils arising from the defective positions of the target and of the gun,

$$\frac{20+30}{4.50}=11 \text{ mils}$$

and the error in the distance used as a basis for computing the range may amount to 50 meters.

Example 3.—In mobile warfare a battery of 75-millimeter guns has been located by a single sight starting from a chapel shown on a map on a scale of 1:50,000. The gun has been aimed with a compass goniometer, the magnetic declination having been taken from a table.

The position of the point of departure, the chapel, may be erroneous by 100 meters on the map. Plotting the point on the plane table on a scale of 1:20,000 may cause a further error, which, added to that of the very scanty measurement, may give 10 meters. The position of the directing gun may be 110 meters in error.

The direction of the aiming line may be erroneous (including an error in plotting) by 20 mils, the declination having been assumed and not deduced from observation on the spot.

A small rectangular wood 4,000 meters away has been assigned as the target (fig. 53). This wood is 50 meters broad

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in the direction perpendicular to the line of fire and 200 meters deep in the direction of the line of fire. It is proposed to adjust the directing gun on the point A (fig. 53). The point A of the map is itself determined only within 100 meters; its plotted position on the plane table on the scale of 1:20,000 may be erroneous by 110 meters. The resultant error for the distance used as a basis of calculation of range may be 110+110 = 220 meters, approximately. The error in the direction may be 75 mils, namely, 55 mils arising from the indefiniteness of the positions of the gun and of the target and 20 mils resulting from the use of the compass goniometer.

FIGURE 53.—Adjustment on a distant wood.

If fire is conducted without an observer the error in range will compel an increase in the number of salvos fired with different ranges. We shall probably not hit the target even with a battery firing at 3,800 meters on 200 meters of front. It is therefore seen that there is an advantage in eliminating the error of 20 mils that arises from the imperfect method of using the compass goniometer.

SECOND PROBLEM.

Example 1.—A piece of high-power heavy artillery is to fire upon a railway bridge. The position of this bridge is known within 5 meters. The bridge is 14 kilometers from the gun. It is desired that the aiming line be fixed within one-half mil and the topographic distance within 10 meters. What method should be used? What instrument should be employed?

None of the instruments used for measuring angles enables us to be sure of the measure of a direction within one-half mil

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except the theodolite. What is more, the theodolite must be used without the compass. Resort should therefore be had to astronomic or geodetic methods. The position of the gun should be determined, starting from points of the general control, by the use of the theodolite. Computations should be used, not graphic methods.

Example 2.—At a station P (fig. 54) the bearing PR of an aiming line is to be determined. This may be done (1) by using

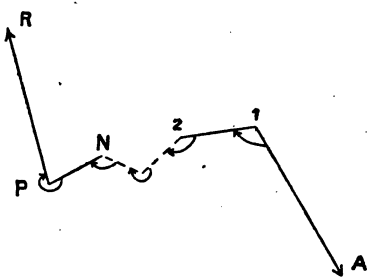

FIGURE 54.—Ascertaining error in bearing of aiming line by means of angle traverse.

an instrument set for declination, occupying the station P, orienting the instrument, drawing the line PR or reading the corresponding axial bearing, the operation being liable to an error α in the line PR; or (2) by occupying a station at a known point 1, orienting the instrument on a distant signal A, and then making an angle traverse passing through the points 1, 2, . . . N, and P.

In this case $2(N+1)$ lines will have been drawn on the plane table or $2(N+1)$ readings of directions will have been made on the goniometric instrument. If β is the error to which each of them is liable, according to the rule given for traverse, the

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error to which PR is liable will be $\beta\sqrt{2(N+1)}$. The angle traverse will be more advantageous if we have—

$$\beta\sqrt{2(N+1)}<\alpha$$

or

$$2(N+1)<\frac{\alpha^2}{\beta^2}$$

or

$$N<\frac{\alpha^2}{2\beta^2}-1$$

N is the number of stations which should not be exceeded. For the various instruments we have:

Instrument.	α	β	$\frac{\alpha^2}{2\beta^2}$	N
Plane table.....	*Mils.* 5	*Mils.* 2	$\frac{25}{8}$ *Mils.* $=3.1$	2
Compass goniometer.....	3	1	$\frac{9}{2}=4.5$	3
Jobin theodolite.....	.5	0.16=1′	$\frac{2,500}{2\times196}=6$	5

The more accurate the instrument used the more may the number of stations be increased. Of course angle traverse is to be used if local deviations are expected, when α becomes very large, but even then there is an advantage in decreasing the number of stations.

ERROR IN THE TRANSFER OF FIRE DUE TO ERRORS IN TOPOGRAPHIC DATA.

Let B (fig. 55) be the position of the auxiliary target, BP′ the direction of the auxiliary target as deduced from the position

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P′ plotted for the gun. If there is no error in the coordinates of the gun, the exact direction will be BP. In making the measurements for transferring fire with a target protractor,

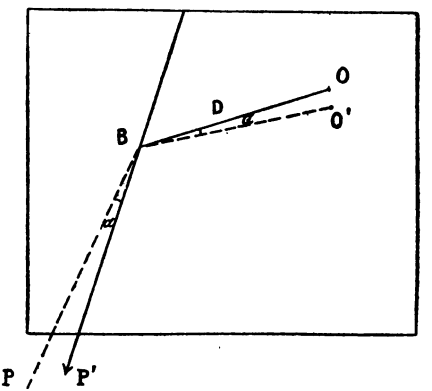

FIGURE 55.—Error in transfer of fire due to inaccurate location of gun.

starting from B, according to the rule, the direction BP′ is used instead of BP. The protractor is set at an angle α—

$$\alpha = PBP' = OBO'$$

O being the target. Instead of the exact elements of O there will be read off the elements of O′ such that—

$$OBO' = \alpha \text{ and } OB = O'B = D$$

The errors in the transfer of fire will therefore result from a displacement—

$$OO' = D\alpha$$

Now, if r is the error in the position of the gun, the maximum of α is—

$$\alpha = \frac{r}{A}$$

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A being the topographic range, and the maximum of the errors in the transfer of fire corresponds to a displacement

$$OO' = \frac{r}{A} D = \frac{D}{A} r$$

In the transfer of fire, therefore, the maximum error in the data for transferring is equal at most to the error in the position of the gun multiplied by the ratio of the distance from auxiliary target–target to the distance from auxiliary target–gun.

REMARKS.

We have given above only a few very elementary ideas in regard to the topographic errors that may affect the preparation for map firing, but the conclusions that may be drawn from the simple examples considered follow equally well from a more profound study of the question. With a good battle map the instruments placed at the disposal of batteries and battalions enable them to obtain excellent results without difficulty. With the map on the scale of 1:50,000 the results are naturally not so good, yet they are still satisfactory. But it should always be understood that the use of topographic methods should not, under any pretext, lead to neglect of observation. The discussions above show this plainly. The great advantages of well-executed topographic operations are, however, to make observation easy, to facilitate and hasten the adjustment of fire, and to secure a gain in time and economy in ammunition.

In all that has gone before we have intentionally considered only topographic errors. The ballistic errors arising from the fact that the conditions at the time of fire do not correspond with the data given in the range tables are considered on pages 121–127. These errors are important, but as they may be determined either by computation (atmospheric corrections) or empirically (correction for the lot of powder, for the weight of the projectile, and for the behavior of the guns) it may be said that they disappear, at least in part, as errors and become in reality mere corrections.

CHAPTER VII.

ARTILLERY INFORMATION SERVICE.[1]

CENTRALIZATION OF DATA.[2]

FORMER AND PRESENT PRACTICE.

The information service in regard to the enemy is provided for, in the staffs of the higher units of the French Army, by the "second bureau,"[3] which is charged with the management and guidance of the agencies of information, with assembling the information received from them, and with studying it and communicating it to the commanders and to various persons concerned after it has been worked up.

In view of the special character which the war has taken on, it has seemed desirable to decentralize the work of these third sections and to intrust to the artillery itself the work of coordinating all data received in regard to its targets, and of communicating them to the battalions and batteries in the precise form and with the precise technical directions that are necessary for the execution of fire. There has therefore been established an artillery information service [Service des renseignements de l'artillerie] in the two superior units of the

[1] See Instructions on the operations of the artillery information service and the agencies for terrestrial observation: Part I, Artillery information service; Part II, Sections for the collection of information by terrestrial observation [Instruction sur le fonctionnement du service des renseignements de l'artillerie et des organes d'observation terrestre: Titre I, Service des renseignements de l'artillerie: Titre II, Sections de recherche de renseignements par observation terrestre].

[2] Taken almost literally from "Instructions on the duties of the artillery service" [L'instruction sur le fonctionnement du service des renseignements de l'artillerie].

[3] Corresponding to the third section of the American Army Staffs. Hereinafter it will be referred to as the third section.

artillery command—that is, in the army corps and in the army. When the artillery information service was established there were attached to it, as was natural, the agencies of information belonging especially to the artillery, namely, the sections for the collection of data by terrestrial observation, previously called section for plotting by gun flashes and sections for plotting by sound. Since then the sections of artillery information service have operated under the conditions stated below.

The artillery information service receives the data from the aeronautic service and from the third section, and adds thereto whatever it obtains by means of terrestrial observations.

AERONAUTIC SERVICE.

The aeronautic data are obtained by reconnaissances and by photographs. They are worked up by the officer in charge of aeronautic information [officier de renseignements de l'aéronautique] in the form of reports of information, hasty plan projections from photographs, and cards for batteries, which are sent either immediately or at the end of the day to the artillery, together with the photographs. When the importance of the information justifies it, the officer who has made the reconnaissance is sent to the artillery to furnish supplementary explanations.[1] During a period of slight activity, and in an army corps that possesses only its usual heavy artillery, the artillery information service finds no difficulty in keeping informed of the results of aerial reconnaissance by wireless telegraph of the command, direct telephone to the balloons, and examination of the aerial photographs, and in discussing them with the observers or officers of the aeronautic information service. During a period of great activity and when the aeronautic service is reinforced the collection and classification of information by the artillery information service becomes more difficult. The artil-

[1] Instructions for the acquisition and study of data [Instructions sur la recherche et l'étude des renseignements].

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lery commander must take special precautions that all information of interest to the artillery information service shall reach it in time to be useful, and that the service shall have all the facilities desired for discussing it with the intelligence officers of the aeronautic service and, if necessary, with the observers themselves. The arrangements to be made for this purpose depend on the general organization of the artillery in the sector concerned and on the corresponding organization of the aeronautic service. In any event, it is indispensable that the intelligence officer of the aeronautic service have a daily meeting with the chief of the artillery information service in order to study and discuss with him the bulletin of information collected by the aeronautic service within the preceding 24 hours.

THIRD SECTION OF THE STAFF OF THE ARMY CORPS.

Data gathered by the third section in regard to the targets of the artillery should be transmitted to the artillery information service by the daily bulletins of the third section, or, in case of urgency, by special notices, or, finally, by direct oral communication from the chief of the third section or his representative. The data so transmitted, which relate to the enemy's organizations, barracks, shelters, railroads, frequented trails, batteries, ammunition depots, observation stations, etc., are derived from examination of prisoners, from reports and sketches furnished by the intelligence officers of infantry, checked and verified by the topographic section of the army corps, from listening posts, and from data and documents taken from the enemy or obtained in special ways.

The third section and the artillery information service are intimately connected. The artillery information service, in particular, should keep in constant touch with the topographic section of the army corps, which communicates to it the results of the plan projections of photographs and distributes to it, as fast as they are made, the revisions of the battle maps, which

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show the new works of the enemy and the exact trace of the front.

TERRESTRIAL OBSERVATION SERVICE.

The information coming from the sections for the acquisition of information by terrestrial observation and for plotting by sound is sent to the chief of the artillery information service by the chiefs of service for the acquisition of information by terrestrial observation and the service for plotting by sound, in the form of telephone communications and daily bulletins, under conditions that he prescribes. On the other hand, information received from observation stations established by batteries, by battalions, or by staffs is sent to the artillery information service in accordance with the instructions given by the artillery commander.

RECORD AND MAP OF THE BATTERIES.

The artillery information service notes and classifies, as fast as it comes in, all information concerning each enemy battery—its nature, activity, successive transformations, exact position, etc. This information is entered on a record or on cards classified alphabetically, and is so arranged as to receive also the summary and conclusions of discussions in regard to it. A map, which is always kept up to date, is made by the artillery information service to supplement this record. This map is revised and replaced periodically, and the series of maps so prepared is preserved with a view to keeping track of the successive changes that have been made in the disposition of the enemy's artillery. When a relief in the service occurs all this record is transmitted to the corps concerned.

COORDINATION OF DATA.

NATURE OF THE WORK.

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The study and coordination of information concerning the tillery targets is the most difficult and delicate part

of the work of the artillery information service. In order to eliminate doubtful items, to pick out what should be taken into account, and to give to each item the weight that it deserves, the chief of the artillery information service should do this work very patiently and methodically. No precise rules can be given for this work, which assumes the most diverse forms, varying according to circumstances. In a general way the following suggestions regarding the value of data obtained from various sources should be kept in mind.

DATA FROM THE THIRD SECTION.

The data from the third section are of great interest and value to the artillery information service, because they include much matter that could not possibly be procured by any other means. In making use of them, however, the artillery information service should consider most carefully the value that the third section assigns to them.

Information furnished by prisoners relative to passageways habitually used by the enemy for reliefs and supplies or relative to his shelters and cantonments may be checked to a large extent by examining the topography of the enemy zone and the general features of his defense as shown on the battle map.

Information relative to false batteries or to batteries concealed in houses, orchards, or woods, or hidden from sight by some artificial mask or disguise [camouflage] should not be accepted unless it is verified by several pieces of evidence. Data so verified prove the existence of the battery described but may afford little accurate information in regard to its precise position.

The results of our artillery fire on the different targets may, in general, be estimated with considerable certainty from the testimony of prisoners.

Finally, sketches and documents found on the enemy give information whose value may easily be inferred from the form in which they are prepared.

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DATA AND DOCUMENTS FROM THE AERONAUTIC SERVICE.

The targets disclosed by aerial photographs can be located with considerable accuracy if there are in the immediate neighborhood any reference points, such as roads or edges of woods, that are accurately placed on the map. A map not brought up to date (a new front or a region for which there is no exact cartographic base) may lead to considerable error in plan projections from photographs. The similarity of the photograph and of the map is, moreover, not a sure index of the value of the map, as there may still be errors in the location of the area in question. Furthermore, as regards batteries, photography shows only the emplacements. The emplacements perceived may or may not be occupied, or they may even belong to false batteries carefully maintained to simulate occupation, with trails of approach, blast of guns, etc. However, in periods when the activity is great and when the enemy has been led, under fire, to reinforce his artillery rapidly, he has, as a rule, no means of setting up false batteries. At such times the enemy also takes fewer precautions to disguise his positions by camouflage, so that the indications furnished by photographs are then much more trustworthy.

The positions of batteries as located by observers in an airplane can not be considered accurate unless they are near some characteristic detail of the terrain that is exactly located on the map, such as a road or an edge of a wood, or unless their positions on a photograph can be indicated exactly by the observer.

Unless the weather is unusually clear, batteries described by observers in balloons can not be located with an accuracy that is entirely satisfactory except in the direction in which the observer has viewed them, and except where the terrain presents very plain reference points, enabling him to minimize errors in estimating distance.

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INFORMATION FURNISHED BY TERRESTRIAL OBSERVATION.

Terrestrial observation does not permit the location of the positions of batteries and other distant targets except by sights taken from several stations according to methods followed by the service for the acquisition of data by terrestrial observation. A location will be considered as probably accurate only if it has been obtained by sights from three stations, the three lines of sight intersecting in one and the same point at rather large angles.

With the instruments now in use determination by gun flashes at night are inferior in accuracy to those made by day. Furthermore, the use of antiflash cartridges and the production of false flashes are causes of difficulty in plotting by flashes or of mistakes against which it is necessary to be on guard.

Plotting by sights from isolated observation stations gives at best only an indication—more or less accurate according to the method of working—of the location of the targets reported. Great caution should be exercised in combining sights taken from different observatories by comparing the times of observation, if observation stations have not that direct connection with one another which enables them to set their watches together.

Plotting by sound is difficult and generally slow work, but it is capable of giving fairly accurate results, the errors being in general of the order of magnitude of 50 or 100 meters when automatic recording apparatus is used. Its accuracy nevertheless diminishes with the distance of the batteries to be located or with the obliquity of their direction with reference to the general base of the section. The accuracy is low in windy weather. The information obtained by this method has the advantage of providing absolute proof of the occupation of located positions and of furnishing often a sure indication of the caliber of the guns.

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NECESSITY OF COMPARING DATA OBTAINED BY DIFFERENT SERVICES.

In investigating and fixing the position of enemy batteries special attention should be paid to possible errors due to the marking or disguising [camouflage] of real batteries and to imitations of activity by false ("Quaker") batteries (flashes, maintenance of approaches, etc.). In general, false batteries are set up near real batteries, often in emplacements once occupied and afterward evacuated in consequence of effective fire of our artillery. Observers in balloons and terrestrial stations may help to remove doubt on this point by noting the agreement or disagreement between the instant of the apparent discharge and the instant of the arrival of the projectile. Plotting by sound will furnish very valuable verification of the occupation of positions.

In a general way, when the enemy's artillery has been reinforced or its arrangement has been for any reason modified, the early data of the various artillery information services are likely to be abundant but not in accord, so that the number of batteries located is apparently very great. The artillery information service endeavors to remove the improbabilities that will be discovered by correcting the positions reported by the observers or the various information services and by putting them in touch with one another if necessary.

COMMUNICATION OF INFORMATION BY DAILY BULLETIN.

METHOD OF PROCEDURE.

The artillery information service communicates to the subordinate artillery commands and units from day to day all accurate information that it has been able to obtain regarding the targets. This information is given in a daily bulletin which is forwarded to the intelligence and operations sections of the army corps, to the artillery information service of neighboring

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corps, and to the army, in three copies (artillery, aeronautics, and range triangulation), and is distributed to the officers down to battery commanders, inclusive. This bulletin is prepared for a period of 24 hours, fixed by the army—for example, for the period between 18 o'clock and 18 o'clock, the work of the artillery information service being done during the evening and the following morning and the bulletin made up and sent out before noon. This bulletin should present clearly and concisely all information which for any reason may be of interest to the artillery and which should be brought to its attention in order to enable it to perform its work under the best possible conditions. The information obtained is classified as follows:

CLASSES OF INFORMATION.

Activity and position of the enemy's artillery.—In addition to the batteries that have been disclosed as in action during the preceding 24 hours, any new emplacements that have been discovered should be described, whether they are occupied or not; also batteries already located whose positions have been determined by new observations. To designate the batteries the bulletin uses the numerical values in hectometers of the coordinates on the battle map. In designating the positions of new batteries, the artillery information service assigns to each of them the number corresponding to its supposed position. This number may be modified later, if necessary, in accordance with fresh information, but it should not be changed after it has been entered on the battle map.

Results of artillery fire.—The results of fire undertaken to destroy the enemy's batteries are recorded, together with a note of particulars picked up during the adjustment or the fire for effect.

Works of the enemy; his general activity.—Most of the information about the enemy's works that particularly concerns the artillery, except that regarding the enemy's batteries, is

mentioned in the bulletin of the third section of the army corps or is entered in the revisions and special sketches of its topographic section. The bulletin of the artillery information service reproduces it in an extract or makes reference to it, giving comment on it in order to furnish, if necessary, details about certain parts of the enemy's works that are to be demolished and indicating the photographs to be examined. Nevertheless, certain distant artillery targets—such as passage points, trails, ammunition depots, supply centers, observation stations, command posts—may require special study by the artillery information service—such as the examination of photographs and detailed maps and the working up of the information furnished by the third section. The result of this study is to be inserted in the daily bulletin as far as possible in the form of sketches, with explanatory legends.

The bulletins of the artillery information service appear and are distributed under the stamp of the artillery. The third section exercises control over them in regard to information other than that pertaining to the enemy batteries.

Except documents coming from the army—that is, from the artillery information service of the army and range triangulation detachment—no documents analogous to the bulletin will be distributed to batteries of the army corps, particularly lists or maps of batteries, unless they have been verified, checked, and approved by the artillery information service of the army corps.

WORK OF THE ARTILLERY INFORMATION SERVICE IN THE IMMEDIATE TRANSMISSION OF INFORMATION.

The immediate transmission and use of information concerning artillery targets is insured by the decentralization of the various information services (airplanes, balloons, observation artillery sections, their central stations or isolated observation stations), which for this purpose are placed to a certain extent

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at the disposal of the groups and commands or directly connected with them under conditions defined by the commander of artillery of the army corps. Nevertheless the artillery information service should obtain all information that is directly transmitted to the subordinate organizations and communicate it to the artillery commander, in order that he may know his opportunities for intervening, and particularly that he may insure a complete utilization of information pertaining to important targets. Furthermore, the artillery information service provides for and controls the rapid transmission to those who are concerned of any information coming from neighboring corps or from the third section that is of a nature to justify the immediate opening of fire. It transmits without delay to the second bureau of the army corps, to the artillery information services of neighboring corps, and to the heavy artillery commands of the army all urgent information that may be of interest to them when it is not certain that this information has already reached them or when it is able to complete or correct it.

To summarize: To insure the immediate transmission of information, the artillery information service acts both as a check for the commander, in accordance with his instructions, and as a connecting link with other organizations for the purpose of transmitting to the various persons concerned all information the working up of which may require their cooperation.

These functions require of the chief of the artillery information service great initiative and activity as well as a perfect knowledge of the organization of the artillery of the sector and of the duties of the various battalions and commands and of their possibilities for firing.

WORK OF THE ARTILLERY INFORMATION SERVICE IN THE ORGANIZATION OF FIRE.

The artillery information service aids in the command of the artillery by establishing and keeping records of the organization

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of the artillery fire of the sector. Identical records are made for each supporting position and include particularly the following features:

(*a*) A scheme showing the commands as organized, with the zones of action of the various units, the location of the command posts and of wireless towers and balloons, and the complete system of connection between the different lines.

(*b*) The general plan of the system of terrestrial observation, of the observation for adjustment and for fire for effect, of the observation by the commander, and of the intercourse of the observation services with one another and with the units and the staffs; the list of coordinates of the observation stations, with maps and sketches giving the outlook from them, information about their use, and special instruction concerning them.

The chief of the artillery information service keeps this record of terrestrial observations with special care in order to be able to inform every unit that arrives in the sector concerning possible points of observation. He ought therefore to know fully what parts of the enemy zone are in sight and the points to which an observer must go in order to observe them under conditions most favorable for adjusting and controlling the fire.

Furthermore, the artillery information service procures for the various units all documents relating to the organization of fire that are required by them. It keeps and distributes to the batteries extracts from the list of points on the battle maps made by the range triangulation detachment. It furnishes to the topographic service of the army corps the copies of the battle maps and of the revisions required by the artillery. It undertakes, if necessary, their distribution, and in every way it makes sure that all units and artillery staffs are well provided with them. Finally, it does whatever is necessary in order that the subordinate units may receive the photographs that are indispensable to them in studying their targets, in preparing their fire, and in verifying results.

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SPECIAL SECTIONS FOR ARTILLERY OBSERVATION.

The sections for terrestrial observation and the sections for plotting by sound, as has been said above, are under the direction of the artillery information service.

SECTIONS FOR TERRESTRIAL OBSERVATION.

The duties of the sections for terrestrial observation are:

1. To keep a general watch upon the enemy zone, particularly the distant parts not watched by the infantry, and to note the works, movements, and operations of the enemy.

2. To locate by intersection the enemy batteries that are visible or that reveal themselves by day or night by their smoke or their flashes, and to identify batteries already known that resume fire.

3. To observe fire by our artillery on special targets, for adjustment or for effect.

MODE OF WORKING.

Each section occupies three or four observation stations, spaced 1.5 to 2.5 kilometers apart on the average and having extensive outlook upon the enemy zone. The targets are determined by intersection by using sights taken from observation stations. Their positions may be determined with great accuracy, but it is necessary first of all that the positions of the observation stations and the initial direction on which the measurements are based should be determined very exactly.

POINTS OF REFERENCE.

It is the duty of the sections to discover and locate targets which are visible under various conditions:

1. Fixed targets, such as the various constructions forming a part of the enemy organization, may be located with great accuracy. The observation station that perceives them points

them out to the other observation stations. The observation stations have all the time they wish to reach a thorough agreement as to the exact position of the target to be sighted. The measurements involve no difficulty. They may be repeated as often as necessary, in order to obtain all desired accuracy in the resections.

2. Mobile targets, such as detachments of enemy troops, convoys, and trains, ought to be located as rapidly as possible. Their route, very commonly marked on the maps (trails, roads, railroads), will aid the observers to point them out to one another and to determine their position at a given moment as well as the direction and speed of their movement. The measurements to be made by the different observation stations should be strictly simultaneous and should refer to exactly the same points.

3. Finally, the enemy batteries that reveal themselves by their flashes or their smoke can not be located with precision except by making several sights simultaneously.

It is to be presumed that such sights really note the same flashes and the same emplacements of the enemy guns. The method of observing flashes from isolated stations and then coordinating the sights by taking the times recorded by the observers is a laborious and uncertain makeshift. The telegraphic equipment used in the service enables an observer at a central office to identify and coordinate sightings made at different observation stations at the same instant. The apparatus at the central office includes a series of electric lights, each representing an observation station, with which it is connected by wire. At the exact instant of sighting, the observer presses a key that lights the lamp at the central office. The observation stations and central office work together in the following manner: An observer, noting a flash or a puff of smoke in a direction or position where none has been observed before, informs the central office, giving the direction and the approximate position of the flash or puff. The officer at the central office, by means of the battle map, on which are

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plotted the positions of the observation stations and of the aiming points, determines approximately the direction in which observers at other posts should sight in order to see the same series of flashes. All then sight on the flashes that are occurring within their surveillance. The officer at the central office follows the operations on the lamp board, interrupting the observers to give them data and to guide them, until there is an exact agreement in the instant of observation of the flash at the several stations, which is indicated by the simultaneous lighting of the lamps by the several observers. The central office then asks the stations to telephone to it the directions read on the goniometers. Even with absolute simultaneity of record several measures of direction are necessary.

Under favorable conditions the accuracy of the result is equal or superior to that obtained by any other method of determining the position of the enemy's batteries. The different guns of the same battery are located in their respective positions. During the day the locating of a new battery is always fairly rapid. At night it may require more time because of the difficulty of orienting the observers as to the direction in which they should observe, and it is also less accurate, for the binocular glasses are then substituted for the monocular telescope.

For locating known batteries that resume activity the method is in general very rapid. If two stations sighting on a flash again find measurements that correspond exactly to sights that previously served to determine the position of a battery (or sights that correspond to its position obtained by some other method and marked on the battle map), the battery that has fired is identified without chance of error.

FIRE FOR ADJUSTMENT.

The sections may be employed in observing the fire of our artillery for adjustment or for control. The operations of the observers are limited to reporting the exact direction of

the observed points of fall. The central office indicates to them the zone in which they should observe. It is advantageous to observe without interruption a series of rounds fired. The measurements corresponding to the observers' sights are sent into the central station, either as they are made, round by round, or at the end of the series. The central station performs the graphic construction necessary to determine the errors in direction and range corresponding to the observed points of fall, and it sends its results to the unit concerned. The technical instructions distributed to the sections give all information that is required for making these determinations. The central office may also, in certain circumstances, limit itself to transmitting to the battery that is firing the observations made and all information necessary for their use, for the purpose of determining precisely the corrections to be made—the azimuth measured by the observation stations for a particular point of the target or for a point chosen as an auxiliary target, etc. This information may have been furnished in advance, so that the battery may prepare a large-scale sketch of the target and the adjustment. Observations may be made at night under identical conditions.

OTHER WORK OF THE SECTIONS.

In principle, all information collected by the terrestrial observation sections that may be of immediate use should reach the unit designated or qualified to use it within a minimum time or should reach the authority whose cooperation is necessary in order to determine how the information received should be followed up and to make decisions relative to its best use. For this purpose the artillery information service gives the necessary orders to the terrestrial observation section. It receives on its part, as soon as possible, all information transmitted by the section directly to the units or the various staffs. The sections should not generally be asked to parti-

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cipate in adjusting and controlling fire except when it is not possible to do so under favorable conditions either by aerial observation or by the aid of a system of terrestrial observation for adjustment. There is a special advantage in resorting to the help of the section for terrestrial observation for targets discovered and located by the section itself and for targets or auxiliary targets of long-range guns, and also in firing at night, which can not be adjusted except by means of directions sighted from several stations. The chief of the artillery information service, in accordance with instructions of the artillery commander, decides on the conditions under which the section should execute the adjustment and make the arrangements necessary to insure its rapid execution.

In the course of a battle and during an advance the sections for terrestrial observation are employed as long as possible under the conditions usually prevailing during a period of stability, their observation stations being displaced successively in order that they may follow the movement of the front, and their connections with one another being provided, if necessary, by expedients of the moment. During one phase of the advance, or immediately after a sudden forward movement, while they are awaiting the time when it is possible for them to act as established sections, they are for the moment broken up into groups of observers placed at the disposal of subordinate commands of artillery, or they are used in work of reconnaissance or in observations of interest to the artillery command.

SECTIONS FOR PLOTTING BY SOUND.

The sections for range finding by sound undertake to locate the enemy's batteries by recording the sound phenomena that accompany the fire, phenomena called "discharge wave" and "shock wave" [onde de bouche, onde de choc]. The discharge wave is produced by the departure of the projectile. The shock wave is produced by the motion of the projectile through the air. This wave is produced only by guns having an initial

velocity greater than that of sound—that is, by high-power guns—as may be shown by the very simple consideration explained below. (See fig. 56.)

Let P be the gun, PX the trajectory, and O an observer. The projectile arriving at some point A of its trajectory, with velocity V, strikes the air, disturbs it, and produces a noise that is transmitted through the atmosphere in spherical waves. This noise

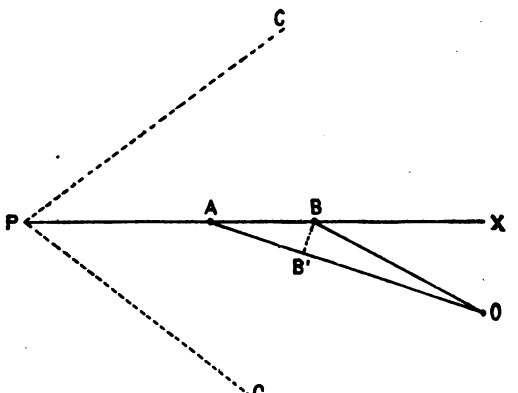

FIGURE 56.—Plotting by sound. Production of a concussion by discharge waves and shock waves arriving simultaneously at a point on one side of the trajectory.

reaches the observer O a certain time after the instant when it was emitted at A, a time T having for its value $\frac{AO}{v}$, v being the velocity of sound in air. A little farther on—at the point B, for example—the same phenomenon is reproduced, and the observer hears at the end of the time T′ the noise emitted at B, the time T′ having for its value $\frac{BO}{v}$.

Suppose that, t being the time required by the projectile to go from A to B, we have $T=t+T'$, then the two noises emitted at A and B will reach the observer O at the same instant.

It is seen that this will happen if $\frac{AB}{V}=\frac{AB'}{v}$, that is to say, if the projection of the velocity of the projectile on AO is equal to the velocity of sound.

Thus for the region AB of the trajectory, in which the projection of the velocity of the projectile on a line directed toward the observer is equal to the velocity of sound, all the sounds will combine and, arriving at the same time, will produce the concussion that is actually heard by the observer. Thus we see—

1. That only guns giving an initial velocity greater than the velocity of sound will produce a shock wave.

2. That outside a certain region to the right and to the left of the trajectory the concussion will not be produced. The extreme limit will be the cone C (see fig. 56), whose vertical angle is such that the initial velocity projected upon the generatrix is equal to the velocity of sound.

3. That for an observer in a definite position with regard to a gun and to its trajectory the direction in which the concussion is heard is likewise very definite, for the velocity of the projectile continues to decrease and thus gives rise to the relation indicated above for a definite region of its trajectory. For guns of high initial velocity and great range having trajectories with a large maximum ordinate, the velocity of the projectile in the descending part of its trajectory may exceed the velocity of sound and give rise to a second point from which a shock wave is emitted.

4. Finally, the concussion will always reach the observer before the sound of the discharge itself. In fact, if the concussion precedes the noise of discharge by only a short time, and if it is more intense, as it is for all the ordinary long guns, it will be the only sound actually heard. The discharge of the gun itself will not be perceived by the observer. In reality these two kinds of sound phenomena are of different physical character, and the ear does not record them with equal ease.

To summarize, what is most often heard in practice is a report that does not come from the gun itself but from a point

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which, for a given position of the observer with regard to the gun, depends on the direction of fire.

Now, an observer who hears the sound of a cannon does not know, except in unusual circumstances, whether the piece which is firing is a gun or a mortar, or whether the noise he hears is the report of a discharge or a concussion; therefore, observers of batteries and groups should never undertake plotting by sound. This plotting can be done only by special sections. It is desirable that observers in the trenches should caution the infantry against gross errors that may be committed by estimating the direction of a gun or of a rifle from the sound.

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CHAPTER VIII.

USE OF TERRESTRIAL OBSERVATIONS FOR ADJUSTMENT OF FIRE.

GENERAL PRINCIPLES.

The search for places from which he can observe the results of his fire is one of the constant duties of the artillerist. The development of means of aerial observation and the perfecting of communication between the aerial observer and the batteries does not in the least permit him to dispense with terrestrial observation, which at many times remains the only method available for adjustment, particularly when the atmospheric conditions are unfavorable for aerial observation or when it is a question of effecting a very accurate fire on the enemy's works close to our lines, of maintaining a barrage fire, or of a like operation. Besides, the increase of telephone facilities makes it considerably easier to organize the work of terrestrial observation, which is no longer confined, as in mobile warfare, to high ground close to the batteries. In actual conditions any point of the ground from which the commander of a battery can perceive his target clearly may become an adjustment observation station. Such observation stations are located (1) in the first line, especially for destructive fire, for opening breaches in entanglements, and for organizing barrages; (2) on dominant points, even at considerable angles and at variable distances, so long as they give a good view of the target and the neighboring ground. The accurate determination of the initial data for fire and the use of good optical instruments enable the artillerist to be certain of the adjustment in spite of the distance.

The examination of the methods of adjustment, strictly so called, is outside the province of these instructions, but the

principles that govern observation for adjustment are given below.

Observation for adjustment, which is generally very similar to observation of surveillance and the determination of the positions of targets, is very often intimately connected with them. As in determining the positions of targets, one observation in a single direction is theoretically insufficient, and the cooperation of two or more observation stations, one of which is as distant as possible from the axis of fire, is desirable in order to effect quickly an absolutely accurate adjustment.

ADJUSTMENT BY SEVERAL OBSERVATION STATIONS.

Methods employed.—When the terrestrial observation stations that have served to locate the target are available for adjustment, the work is done under the most favorable conditions. In practice the sections for terrestrial observation will then proceed to the adjustment, but battalions and batteries may take it up on their own account, using their own observation stations, the observation stations of neighboring units, and the observation stations of the general system for adjustment that have been placed at their disposal. It is then necessary to proceed in a manner analogous to that described in the technical instructions of the sections for terrestrial observation.

When the positions of the observation stations have been exactly determined and the directions of the aiming lines are well known, shell bursts are located as follows:

1. The position of the target X is given by its coordinates, x and y. Construct the point X′, the intersection of the sights made by different observation stations upon the point of burst; by projecting the point X′ upon PX, P being the gun that is firing, we obtain the corrections in range and in deflection.

2. If the target can be sighted from different observation stations during the adjustment (with the target constantly or intermittently visible) the adjustment is always made by con-

structing the point of burst from the intersection of the sights, which are referred to the direction of the target by subtracting the angular reading of the last goniometer sight made on the target from the reading of the point of burst. This method of procedure has the following advantages:

(*a*) The errors in range and deflection are independent of those in the position of the target.

(*b*) The errors do not depend on the errors in the position of the observation station, if the common reference point is near the points of burst.

(*c*) Finally, if the target is moving or changing (gun on railway, neighboring guns firing in succession) the method enables the artillerist to follow the changes and to modify the adjustment.

The principles of observation just laid down for observation stations with distant outlooks, equipped to take accurate sights intended to be combined by intersection, are equally applicable to the observation stations of the units. It is well to be guided by them for all adjustment made under these conditions.

To facilitate the rapid plotting of observations and of points of burst, it is desirable to prepare a sketch of the target.

Sketch of the target.—The map showing the target is a large-scale map (1 : 10,000 or 1 : 5,000, squared), representing the zone of the target. This map, made by the range triangulation detachment of the army, does not invariably contain all the details visible on the photographs that might concern the batteries and be of use to them, particularly in adjusting by airplane. It is therefore necessary that the orientation officers complete this map by supplying such new details as appear to them to be of value.

When once the map has been laid out and completed, it should be placed on a special board and prepared in such a way that it may be employed rapidly to record and use the information received from observers, to measure off the data for correcting the fire for adjustment, and to measure the topographic data

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for the transfer of fire, if the adjustment is not on the target itself but on a neighboring point. If there are several neighboring targets, prepare for each target a piece of tracing paper with reference marks, which will then have merely to be placed on the map.

Begin by drawing on the map showing the target, or on the tracing paper, the line gun–target. This line will be drawn according to its computed axial bearing if possible. Construct on each side of this line an arc in mils or in decigrads, and in the vicinity of the target graduate the line itself in units of distance. The arc in mils may be made by two graduated scales. It will be sufficient to join the two corresponding points marked with the same number in order to have a given deflection. Then draw the lines of observation and the corresponding angular graduations, in order to be able to construct the impact of a projectile as seen from the observation stations. Use a different color for each observation station in order to avoid errors. To make all the constructions which this preparation requires it will be convenient to make use of protractors for the different distances on the scales of 1 : 10,000 and 1 : 5,000. These protractors, which are on tracing paper or tracing cloth, are called target protractors. If none are at hand, the angular graduations may be made directly upon the map by calculating the coordinates of three points at three different distances for several directions corresponding to round numbers of mils and then interpolating between these directions.

ADJUSTING BY A SINGLE OBSERVATION STATION.

In spite of the theoretical advantages of adjusting by combined observations (bilateral or trilateral observations), it is frequently necessary, in the units, to adjust from observations made at only one station. Doubtless such observations are often easier, either because the observation station is near the battery and the line of fire or because it is near the target. Furthermore, these stations are chosen so as to give a good view of the

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ground surrounding the target, ground which often presents reference points that are very useful to the observer. In no case, however, do these favorable circumstances permit the observer to be satisfied with taking a rapid glance at the points of fall and forming an opinion on their positions based upon his impression alone. The observation should be made in a rational and methodical way, in order to avoid all groping about and all loss of time in adjusting. The first precaution to be taken is to determine the position of the observation station.

Strictly speaking, the determination of the coordinates of the observation station does not need to be so accurate as that of the coordinates of observation stations intended to locate targets by intersection, but all hope of attaining an adjustment must be abandoned if the point from which observations are made is not known approximately at least.

Whether the observation of the fire is made at a short or at a long distance, whether it is more or less oblique, it consists always in observing the direction and, if possible, the magnitude of the deviations with reference to the line of observation. It should be possible to deduce from these observed deviations some sure indication of the topographic position of the points of fall with reference to the target. The determination of the position of the observation station for noting the fire must be so accurate that the direction of the line of observation may be drawn on the map in the vicinity of the target.

If the observation station for fire is distant from the front, its position is determined by ordinary topographic methods (plane table) based either upon the general control or upon the planimetric details of the topographic map. If the observation station is in the first-line trenches, it may sometimes be located by the three-point method from points of the general control (as by a round of the horizon with the binocular telescope and construction of the point with tracing paper), but most often it can be located only with reference to the trenches and communication trenches of the battle maps. When this has been done, if the tar-

get is close by, it is advisable to verify the orientation of the line of observation by sighting with a compass. Verify at the same time the respective positions of the observation station and of the target.

Example.—Let P (fig. 57) be the point of the enemy trench on which it is desired to adjust from the point O in our first-line trench. A sight made at O on P with a Peigné compass gives the direction PO. As the point P is exactly located on the map (intersection of a trench and a communication trench), the exact position of O is deduced from it, being at the intersection of the line PO and the trench T marked upon the map.

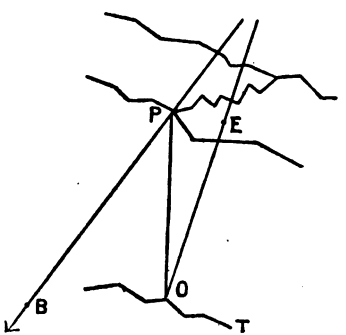

FIGURE 57.—Method of locating an observation station in a trench.

If the trench T has not yet been marked or if the point O is off the map the line OP may be measured with the telemeter or estimated with the help of the details of the map. If no compass is available for taking the direction OP, or if it can not be used, a periscopic instrument—such as the periscopic binocular or the periscopic gonicmeter—may be used to measure the angle that OP makes with a reference point, which should be as distant as possible and be given, at least approximately, upon the map. The angle thus measured gives, even with the

approximate position of O, a direction of OP sufficiently accurate to be used in the same way as the direction obtained with the compass.

When the burst E of a shell has been observed measure the deviation from OP of the line OE. The distance OE is estimated by making use of reference points in the region of the target (trenches and communication trenches), or points whose position we have been able to determine previously by simple methods. The point E having been located on the map or large-scale sketch used, the correction to be made by the battery is immediately deduced from it.

The example above is only given as a specimen. What should be remembered is the necessity for determining, first of all and with accuracy, the direction from observation station to target, either its absolute azimuth or its direction referred to the line battery–target. This direction should be known to the observer and to the officer conducting the fire. The usual rule, which consists in firing on the line of observation and of adjusting by means of further rounds on this line, can not be followed if this first condition is not realized.

It should be noted, further, that when the observer is placed far to one side of the line of fire—that is to say, when the angle gun–target–observation station is considerable—the dispersion in range renders impossible the direct application of the above rule. It is then desirable to fire a series of rounds of which the mean points are taken. To do this with rapidity and accuracy requires that the observer should take each time the angular measures indicated in the preceding example, instead of being satisfied to observe merely the direction of the errors.

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CHAPTER IX.

DUTIES OF ORIENTATION OFFICERS.

RELATIONS AND GENERAL DUTIES.

By reason of his special training the orientation officer is usually the assistant of the major in all questions pertaining to reconnaissances, to the preparation for fire, and to observation, but this statement of his principal duties does not at all imply that the major may not assign to him other duties. The orientation officer lives near the major, and in the nature of things is informed of all that happens within the battalion. The telephone service, though it is not regularly in his charge, is nevertheless intimately connected with the observation service of the battalion, which is one of his particular duties. The wireless service, which also is not in his charge, nevertheless concerns him very directly, for by means of it he can obtain at once the results of aerial reconnaissances. Finally, questions of ammunition interest him necessarily, for he should know what bombardments have been carried out, those that are planned, etc. It follows that the very nature of his duties puts him in touch with the entire activity of the battalion, so that the battalion commander will necessarily, in case of need, intrust to him multifarious duties.

In practice the rôle of the orientation officers is of considerable importance, and they should bear in mind that they have been chosen to fill it by reason of their fitness and their energy. They should prove their initiative under all conditions. They should never wait passively for orders under the pretext that, being subordinate to the major, they have only to do what he expressly orders. On the contrary, it is their business to perform themselves all work that pertains to their duties, which have been defined, once for all, on broad lines by the commander.

DUTIES OF ORIENTATION OFFICERS IN POSITION WARFARE.

DUTIES DURING A PERIOD OF STABILIZATION.

CLASSIFICATION OF DUTIES.

The duties of the orientation officers during a period of stabilization may be classified as follows:

1. Reconnaissance of positions of batteries and measurements connected therewith; study of routes and approaches.
2. Study of the zone of action of the battalion.
3. Organization of the observation service of the battalion.
4. Information service within the battalion.
5. Establishment and maintenance at the battalion headquarters of the records of the organization.
6. Distribution to the batteries of all necessary data and documents pertaining to fire and to observation; providing them with topographic matter and matter obtained by observation.

RECONNAISSANCES OF POSITIONS OF BATTERIES AND MEASUREMENTS CONNECTED THEREWITH; STUDY OF ROUTES AND APPROACHES.

The emplacements for the batteries of a sector are divided into two classes. Some are occupied by batteries, most of which have been there for some time. Others, which have been picked out as second positions for these batteries or as positions for batteries to reinforce the artillery of the sector, are for the moment vacant. The measurements to be made by the orientation officer at each of the occupied emplacements will generally be only verifications of the surveys made by the batteries themselves, surveys which, moreover, have been to a certain extent checked by the results of the artillery fire.

For the unoccupied emplacements, on the contrary, the measurements are all to be made by the orientation officer. These measurements deal with the positions of the directing guns, the aiming lines, and the limits of the field of fire of the guns.

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These measurements will be made by topographic operations on the ground and by study of the maps, as has been already explained.

The positions of the directing guns will be given by their coordinates. The aiming line, defined by actual objects on the ground and determined topographically, is in principle defined by its bearing with regard to the system of squares on the maps, its angle being expressed in grads or in mils or represented graphically on the plotting board. It may also be defined under the same conditions with respect to the presumed direction of surveillance, corresponding to that of a well-determined point on the map situated about the middle of the zone of action of the battery.

As an aiming point that defines the aiming line on the ground is liable to disappear, several such points should be given. Moreover, as the battery may have to begin its first operations either at night or in foggy weather, it is necessary either to take or to make artificially an aiming point that is only a short distance away. The data to be furnished in regard to the aiming line, in order to be complete, should include all facts relative to the supplementary aiming points—a description and the direction of each of them.

The limits of the field of fire of guns are defined in range by considering the maximum range of the gun, the minimum elevation imposed by the protecting mask, and the slopes of the ground which give rise to dead angles; in direction, by considering the condition of installation of the guns—in casemates or on special platforms. The result of this study can be represented only on a map that shows at a glance which parts of the ground can be reached by the different guns of the battery and which fall within dead angles.

The routes and approaches used by each battery in taking up its position are carefully studied with a view to movements either by day or by night. The same study is made of whatever concerns movements between the combat train and the battery.

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The results are represented on a sketch, or, better, on a battle map bearing an explanatory legend that includes all useful comments.

STUDY OF THE ZONE OF ACTION OF THE BATTALION.

The study of the zone of action of a battalion should be made in a very broad way. It should deal not only with the zones of action normal to or possible for the batteries of the battalion at the location where they are at the moment, but also with the entire enemy area corresponding to the zones of action of neighboring units that may participate in activities of the battalion and with the zones of action of batteries that may come up and occupy the reinforcing positions of the sector. Consequently the orientation officer should have a thorough knowledge of an extensive area of the enemy zone. His duties in the organization of the terrestrial observation of the battalion and in the information service pertaining to its targets, considered in the light of what is said further, will enable him to make this study for the area normally under surveillance by the battalion.

In order to complete the study in matters that concern the other areas and the other classes of targets about which he should collect the same data, it is necessary that he should keep in close touch with the infantry of the sector, who will furnish him very valuable information concerning the first-line enemy positions, and that he should keep similarly in touch with neighboring batteries and battalions. He should visit their observation stations periodically and ask of them a copy of each of their panoramic sketches.

ORGANIZATION OF THE OBSERVATION SERVICE OF THE BATTALION.

The observation work of the battalion is a work of surveillance independent of observation by the batteries, which has for its purpose, besides surveillance, the adjustment of fire. The commander of the battalion may organize the observation work

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through his orientation officer, who will therefore have to concern himself with the choice of observation stations and their equipment; various topographic determinations (position of the observation station, bearing of the reference direction, or the point of the map serving as a reference point); preparation of panoramic sketches and various maps for the observation station; instruction of the observers and organization of the service.

Furthermore, the major may intrust the orientation officer with verification of the surveys made by the batteries of the positions of their observation stations and of their aiming lines. This verification will be necessary if the measurements taken at these observation stations are to be used to locate targets by intersection.

INFORMATION SERVICE WITHIN THE BATTALIONS.

The subordinate units of the artillery do not confine themselves to receiving the information concerning their targets that is regularly sent to them by the artillery information service of the army corps. They endeavor to collect some of their own information, in order to perform as fully as possible the duties that are assigned to them, and also to contribute as much as possible to the general information that is centralized at the headquarters of the army corps by the artillery information service. It is first by terrestrial observation and second by the study of photographs that the battalions and batteries can make more definite and complete the information concerning targets given in the bulletins of the artillery information service.

The orientation officer is particularly qualified to perform this service within the battalion. Following the instructions of the major, it will be his duty to centralize all information gathered by the observation stations of a battalion. He should study the photographs dealing with the targets of the batteries and, whenever occasion arises, should transmit to the artillery information service in simple form the results of his labor. He should also

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always transmit these results to the batteries, and also, at the same time, all photographs that may concern them, particularly those which show the results of their fire.

ESTABLISHMENT AND MAINTENANCE AT THE BATTALION HEADQUARTERS OF THE RECORDS OF THE ORGANIZATION OF FIRE.

It is imperative that all information about the emplacements of batteries, their fields of fire and targets, the observation stations of a sector and their outlooks, etc., should be collected at the battalion headquarters. The purpose of this record, the keeping of which may devolve upon the orientation officer, is to prepare for the major those indispensable memoranda that will enable him, when he is relieved, to pass directly along all information that his successor may need to perform his duties without difficulty, as well as to form a collection of all information that may be useful to reinforcing batteries that may arrive in the sector.

To meet these different requirements the record should include documents of two different forms. The documents of the first class will be diagrams, clear and expressive, not aiming at precision but striking to the eye, and enabling the major to take in quickly matter of special importance to him—the location of his batteries, their possibilities of fire, their normal and possible zones of fire, the location of the targets, the arrangement of barrages, the plan of concentration or an extract from this plan, the disposition of the means of observation, the liaisons, the locations of the combat train, etc. This same information will of course be reproduced for the benefit of the reinforcing batteries of the sector and for neighboring batteries.

The documents of the second class, intended for the batteries, should be, on the contrary, precise and detailed. They should include an extract from the triangulation control, the list of coordinates of the directing guns of batteries in position and of reinforcing batteries, the indication of their aiming lines, the

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limits of their exact field of fire on the battle map, the coordinates of all the observation stations of the sector of the battalion, their aiming lines, copies of the panoramic sketches of each of them, and copies of the fire records of batteries which have left the sector and whose emplacements are at the time unoccupied.

The work of preparing these documents will not involve the making of the plane-table sheets of the batteries themselves, which would result in accumulating at the battalion headquarters a cumbersome lot of material. The batteries receiving the data indicated above may prepare their own plane-table sheets very easily, and if provided with an up-to-date battle map they have all the data desired for preparing their fire. Under certain conditions, however, the 75-millimeter batteries and howitzer batteries should do their plotting directly on the map.

All these documents should be also, in the double form indicated above, in the hands of the next higher authority—such as the commander of the divisional artillery or of the heavy artillery.[1] It is the duty of the major to specify exactly the nature of the documents which the orientation officer should prepare, either as originals or as copies of those kept with the colonel, and to fix the sector and the zone of action to which they should relate. Models of these can not be given; they must be prescribed by the battalion commander.

Besides the documents indicated above there should be mentioned certain documents which are used more particularly by the higher authorities of the artillery command, but which may concern the orientation officer of the battalion, for the commander of the battalion frequently becomes commander of a larger organization. For example, the artillery commander, in order to maneuver easily and rapidly the fire of his artillery, needs to have a map so arranged that he can instantly see the possibilities of fire of each battery. His assistant or the orientation officer will prepare this map for him under his

[1] Maps appended to Notebook of the artillery commander of the Sector [Carnet du commandant de l'artillerie du secteur].

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instructions. There are various methods of preparing such a map. Among the most simple and the most practical may be mentioned the one that consists of sticking into the battle map (fastened to a board or to the wall) pins or needles at each emplacement of the batteries of a command. A colored thread, indicating the caliber, attached to each pin, carries a mark corresponding to the limit of the range of the battery. It is, therefore, easily seen whether a target may be reached and by what batteries.

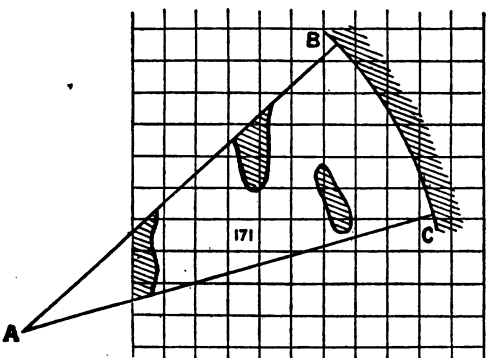

FIGURE 58.—Map showing field of fire of a battery.

To prepare plans of fire concentration, the following method may be used: Cover the battle map on a scale of 1:20,000 with a sheet of tracing paper marked off into squares of 2.5 millimeters—one-fourth of the ordinary squares. (See fig. 58.) Stick a pin in the emplacement of the battery A and show its field of fire by two threads AB=AC=range corresponding to the maximum elevation. Place on BC an arc of a circle made of paper with radius AB. By taking into account the minimum elevations in different directions and the zones within the dead angles the limits of the areas that may be reached within the interior of the sector BAC are traced. Mark in each square

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or fraction of a square that can be reached the number of the battery A—say 171, for example. Repeat the operation for each battery. The result of the work on the tracing will be a very simple and clear document, enabling anyone to make up without difficulty a plan of fire concentration of the artillery of the command.

DISTRIBUTION TO THE BATTERIES OF DATA AND DOCUMENTS PERTAINING TO FIRE; PROVIDING THEM WITH TOPOGRAPHIC AND OBSERVATIONAL MATERIAL.

The orientation officer distributes to the batteries of the battalion the documents which they need—battle maps, revisions of the topographic service of the army corps, sets of instructions, new range tables, bulletins of the artillery information service or extracts from these bulletins (completed and explained, if necessary, by data obtained from the battalion, aerial photographs, etc.).

This distribution should not be a mere transmission, such as a secretary might make, of the documents that have reached battalion headquarters. The orientation officer should be constantly informed of the needs of the batteries, and should do what is necessary to meet these needs with the least possible delay.[1]

These duties of the orientation officer extend very naturally to the topographic and observational material of the batteries, which should be always complete and in good condition.[2]

DUTIES IN THE PREPARATION OF AN OFFENSIVE AND DURING ITS PROGRESS.

If all the work laid out in the preceding pages of this chapter has been carefully done, and if the records of the battalion are

[1] Requests for maps should be addressed to the divisional or corps artillery or directly to the topographic service of the army corps.

[2] Requests for supplies or for renewals relative to this matériel should be addressed to the range triangulation detachment of the army by the chief of artillery of the army corps.

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complete, the reinforcement units, as fast as they arrive in the sector, will receive all information that they need in order to occupy their positions. For them, organization of fire will be rapid, and they will be able to perform their work with very little delay. The orientation officers and the assistants to the chiefs concerned will get in touch with one another on this point, and will give one another mutual assistance, making together, if necessary, reconnaissances on the ground in order to verify the information which they have to communicate to one another.

Besides these operations relative to reinforcing the artillery of the sector, it will be necessary to foresee and to prepare for the forward movement of the artillery. In each battalion the orientation officer should actively prepare himself to perform the part which will be assigned to him by the commander of the battalion during the projected operations and in executing the intended forward movements.

Knowing the zone into which the battalion will have to advance, the orientation officer should study it minutely, first on the map and then by going to the observation stations, considering the area not only with respect to possible battery positions but also with respect to approaches which may lead to them. In order to facilitate and hasten the survey of the positions, which must be made when the time comes, he should determine in advance, by intersection, a certain number of points in this area, selected in such a manner that there will be no fear of seeing them disappear or of not being able to recognize them when they are approached—mounds of earth, conspicuous spots, considerable remains of diverse structures. Furthermore, he should complete, if necessary, a system of points in the rear, in order to establish for the batteries reference points which will be clear and absolutely certain in position. All these supplementary points should be indicated to the batteries by their coordinates, and the indication should be accompanied by a sketch that will enable them to be recognized without ambiguity.

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This preparatory study should also deal with locations for observation stations capable of being used in the course of the successive phases of a forward movement. The personnel that will be intrusted with the observation work of a battalion should be very carefully prepared by the orientation officer to carry out the duties that will devolve upon them at this time. In general, these men will be scouts. Each of them should be informed in advance of the task that will be intrusted to him during the reconnaissance of the positions, of the installation of the observation station, and of the early organization of the service. The orientation officer should have them study in advance the map of the whole area with which their observations will deal and the points that presumably will be selected for the observation stations. This study should be supplemented and made accurate by reconnaissances carried to greater or less distances from all the observation stations of the sector or of the neighboring sectors that afford a view of the terrain under consideration.

From the time when an artillery preparation has been begun the orientation officer should give all his attention to keeping the information service in the battalion working as completely and perfectly as possible. He should transmit to the batteries photographs showing the destruction accomplished. When the first attack has been made and the front changed he should communicate to them all information that he has been able to procure about the new line of front of the sector and of the neighboring sectors, so that batteries may sometimes be informed of the modifications of the front even before they receive the revision notices of the army corps. The orientation officer may also be able to make these notices more definite in certain respects.

When the forward movement of the battalion—either as a whole or in echelon—is under consideration, the orientation officer should be most active in helping the major with the preparation on the ground for the intended movement, and in assisting the batteries to execute it rapidly.

The first reconnaissance of the new positions, of the routes for the batteries, of observation stations, and of the stations to be used for optical communication will vary greatly according to circumstances. During these operations it is the duty of the major to determine the work of the orientation officer, who should, however, submit proposals to his chief concerning all questions coming within his sphere, particularly those concerning the location of directing guns, of aiming lines, and of observation stations. It is important that this small-scale organization of the fire of the battalion should be accomplished without any delay, and for this purpose it is desirable that in all critical or difficult situations the specialists of the battalions shall personally participate.

When the batteries have taken up their positions, the orientation officer should report to the commander of the battalion the precise conditions of their installation and furnish him all the information on this point that he would usually collect, especially information about the exact positions of the directing guns and the aiming lines, the possibilities of fire of each battery, and the principal observation stations of the batteries, their positions, and their outlook.

Finally, the orientation officer should not forget that when the batteries have made a forward movement, and during the first stages of their installation in the new positions, their observation service has generally not yet been satisfactorily organized. The observation stations, not yet being equipped, are not easily available for work of observation, the regular liaisons are not in working order (often they are not even established), and the observers have only an insufficient knowledge of their zone of observation. Therefore the surveillance of the zone of action of the battalion is not completely attained by the batteries. This happens just when the enemy, being more or less in disorder, sends up fresh units as reinforcements, which, arriving in haste on unknown ground, disclose themselves imprudently and might be very easily reached if the enemy zone was being carefully watched.

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At this time, therefore, it is absolutely necessary that the observation work of the battalion should be carried on as efficiently and as thoroughly as possible. It is the duty of the orientation officer to organize it by making use of the scouts of the battalion.

DUTIES OF THE ORIENTATION OFFICERS IN MOBILE WARFARE.

In mobile warfare the duties of the orientation officers will naturally be very similar in principle to those that were intrusted to the officers attached to the commanders of battalions of 75-millimeter batteries at the beginning of the war, but the introduction of new factors and the possibility of using henceforward means of action that have come into everyday use—such as the telephone, optical communication, and especially aerial observation with the wireless telegraph—and also the task of applying the various lessons that the war has taught, will require in practice considerable modification in the methods of making reconnaissances and observations and in firing—work that is normally the duty of the orientation officer. It is imperative that the orientation officers should prepare themselves for their new work and that they should teach and train all the personnel of the scout service whom they have under their control. The exercises and maneuvers in the instruction camp will enable them to accomplish this preparation of their scouts.

In reconnaissances the orientation officer will try to work very quickly, taking his work in the order of urgency corresponding to the necessities resulting from the situation of the battalion and the orders and instructions of his major. Whether it be reconnaissances of routes or positions of batteries or of observation stations, the information should always be in the form of a very plain sketch, with annotations or with an accurate report appended, that brings out the exact points of interest to

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the authority for whom it is intended—the commander of the battalion or the commander of the battery.

These sketches, whether planimetric or perspective, should always carry the names and notes of the topographic map or of the battle maps that will enable anyone to locate or to use the points without difficulty. Each document should bear a title, the name of the author, and the date when it was drawn up (day and hour). A note should set forth its degree of accuracy and should state what confidence may be put in it as a result of the conditions under which it was made.

As a rule, the orientation officer should keep the originals of all documents that he may distribute, in order to refer to them later and to permit his major to keep informed about data sent to the batteries.

Of his personnel of scouts the orientation officer should require habits of accuracy corresponding to his own. He should teach them to submit their information on maps or on very simple oriented sketches and to report to him by this means.

During a period of mobility he will often have to make an orientation in a strict sense of the word. In this case the compass will enable him to work very rapidly and with certainty under all conditions. If the plane-table method can not be used the compass goniometer, or even the Peigné compass, should be used to make the round of the horizon, or, finally, the ordinary compass should be combined with the sito-goniometer to measure angles. The result of his round of the horizon should always be in the form of a sketch, reduced, if necessary, to its simplest elements and indicating only the essential facts, namely, the position of the point where the round of the horizon was made (as derived from this very reconnaissance) and the direction of the principal conspicuous points, by giving their bearings or their angular difference in deflection referred to some reference point and their distances.

In the matter of surveys dealing directly with the firing—namely, the surveys of the positions of the batteries and aim-

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ing lines—the orientation officer can render valuable service to the batteries. He will generally have reached the position before them and will have time to get the bearings of the points in the neighborhood on which they can rely to make their definitive determinations after the emplacements of the directing guns have been decided on by the battery commanders.

In the same way the orientation officer, who will have plenty of time to orient his instruments by compass and to determine the direction of visible reference points in the zone of the battery, will be able to help batteries to determine very rapidly and with certainty the direction of their first fire, which is, as is well known, a matter of fundamental importance. It should not be forgotten that very satisfactory accuracy can be attained by locating the position of the battery merely by the help of the surrounding planimetric detail on the map on the scale of 1:20,000 or, in default of the battle map, on the map on the scale of 1:50,000, and by determining the direction carefully with the help of the theodolite or of the compass goniometer.

Of course all the information pertaining to this summary organization of fire is sent to the batteries in the form of a sketch prepared in very clear form.

This participation of the orientation officer in the determinations of data for the batteries will be required whenever the complete daylight reconnaissance can be made only by the major, the batteries being due to arrive and to begin firing that same night.

The orientation officer should always be actively occupied in observation work. As the terrestrial observation of the group has for its purpose the study or surveillance of the enemy zone or the control of fire, it should be organized under his care, by means of all methods of communication as they become successively practicable—couriers, optical signaling, and telephones.

Finally, in mobile warfare, the orientation officer will be very frequently intrusted with the duty of keeping in touch with the infantry, a service which can not in general be organized by

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using the personnel of the batteries. He should perform it himself or use for the purpose those scouts that are most skillful in performing this work. What he should do in this case depends essentially upon the situation of the moment and upon the orders he receives from his major.

In the execution of these orders he should always take the initiative, endeavoring to conform to them above all in spirit and not in letter only, particularly when the situation changes. Furthermore, he should always consider himself as, for the moment, being to a certain extent a part of the unit with which he is in touch. He should inform the officers of the unit of all that he himself knows about the situation of the battalion or of the neighboring units, communicate to them all orders and instructions that he receives, and show them all reports, sketches, and documents that he is making for his own battalion. The liaison with the infantry is made not merely for the purpose of obtaining information for the personal benefit of the artillerist but for complete and intimate collaboration and cooperation with the arm of the service that is doing the fighting.

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CHAPTER X.

INSTRUMENTS AND METHODS OF USE.

BATTERY COMPASS GONIOMETER.

(For field use, 1916–17 model.)

GENERAL FORM AND PARTS.

The battery compass goniometer is an instrument that is easily carried about and is intended for use in rapid topographic operations and for preparation for fire with matériel provided with an aiming apparatus divided into 6,400 mils. There are two models of goniometer, the 1916 and the 1917 model, which differ only in a few details. The instrument includes a prismatic telescope (containing two prisms, the same as Bausch & Lomb prism-binoculars) of large field and a compass, both telescope and compass being attached to the upper plate Q. (See Pl. IV.)

Telescope.—The telescope is movable in a plane that is vertical when the instrument is set up and that is practically parallel with the zero line of the needle. It can be leveled with the aid of the level V, the movement in elevation being controlled by the tangent screw U. It is a small prismatic telescope with a magnifying power of about 4 diameters. In the 1917 model the eyepiece has a focusing adjustment.

The micrometer of the telescope includes a vertical cross hair for horizontal pointing and a set of graduations for the angle of site from —100 to +100 mils. The optical axis is defined by the intersection of the vertical line of the micrometer and of the zero mark of the site scale. To the right of the cross hair a dotted line gives the normal height of burst of 3 mils.

Compass.—A needle lifter D (Pl. III) permits the arrest of the needle when the instrument is being moved. When the instrument is to be moved the lifter should point to the right. A small prism at the side of the eyepiece of the telescope enables the

operator to observe with precision the needle as well as its zero point.

In the 1917 model alone the zero point of the needle is adjustable by a small screw at the base of the support of the prism, so that two compass goniometers can be set exactly alike for declination.

Horizontal movement.—The upper plate, carrying with it the compass and the telescope, moves over a lower plate. A rapid movement can be given by pushing in the eccentric disk W (Pl. IV) as far as it will go; a slow movement can be given by turning the milled head T. After having used the rapid movement be sure that the disk has entirely returned to its original position under the action of the spring. If it has not returned, do not try to raise it by hand but continue turning the milled head and the disk will raise itself.

The whole instrument can be revolved without disturbing the relative position of the two plates and their graduations. A rapid movement can be given by releasing the clamp screw C (Pl. IV) and a slow movement by turning the abutting screws S after the clamp screw C has been tightened.

Verticality of axis.—The axis of the goniometer is fixed on the tripod by the spindle R (Pl. IV), which is clamped or released by the clamp screw G. A small circular level H, attached to the lower plate, serves to make the axis vertical.

Tripod.—The tripod consists of three telescoping legs and of a vertical sliding tube which can be clamped in any desired position by the clamp screw B. In using the 1916 model for precise topographic surveys it is advisable to leave the vertical tube in a low position. In the 1917 model this movement is better regulated, and we can use the entire range of play of the three legs and of the vertical tube to vary the height of the instrument from 0.80 meter to 1.80 meters.

Graduations.[1]—The compass goniometer is graduated continuously from 0 to 6,400 mils and has subdivisions of 100 mils on

[1] The French wording of this paragraph is not clear, and this translation may therefore be inaccurate.

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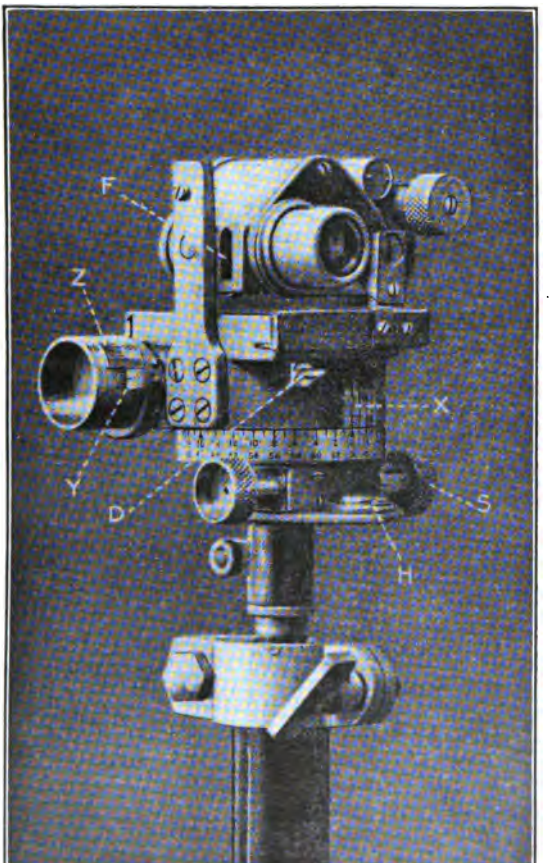
the lower plate, to which the index mark X (Pl. III) on the upper plate refers. The drum carries on its left side, opposite the index mark Y, graduations in mils from 0 to 100. In the 1916 model these graduations bear a double series of figures, a series of red figures on the lower plate and on the left side of the drum, numbered clockwise, and a series of black figures on the lower plate and on the drum, numbered in the opposite direction. The 1917 model bears only the red series.

As the compass goniometer is intended especially for the 75-millimeter batteries, it is equipped with an auxiliary arc that permits the direct reading of differences in deflection (plate, so much; drum, so much) when it is used in directing fire very near the battery, a contingency that was originally provided for by the battery telescope. The reading zero of the continuous graduations (when the index mark X (Pl. III) is opposite the 0 mark of the lower plate) corresponds to the reading plate, 0; drum, 100 of the auxiliary graduations.

One of the quadrants of the upper plate of the compass goniometer is divided into 8 sectors, marked $\frac{PL}{0}, \frac{PL}{2}$, etc., up to $\frac{PL}{14}$. These graduations of the upper plate are read with the four black triangular index marks on the lower plate numbered 0, 16, 32, and 48.

Readings are made as follows: Plate, so much (included in the sector opposite one of the four triangular index marks). Each plate sector of the graduated quadrant has a smooth part and a part cross-sectioned in red. If the index mark of the lower plate is opposite a smooth part, the fractional reading, which then lies between 0 and 100, is read on the drum opposite the index mark Y (Pl. III) by means of the red figures on the left side. If the index mark of the lower plate is opposite a part cross-sectioned in red, the fractional reading then lies between 100 and 200 and is read on the drum opposite the index Z (Pl. III) by means of the numbers on the right side.

Illumination for night observations.—The apparatus for night work includes a battery case, a battery, a rheostat, a switch, a



DETAILED VIEW OF COMPASS GONIOMETER.

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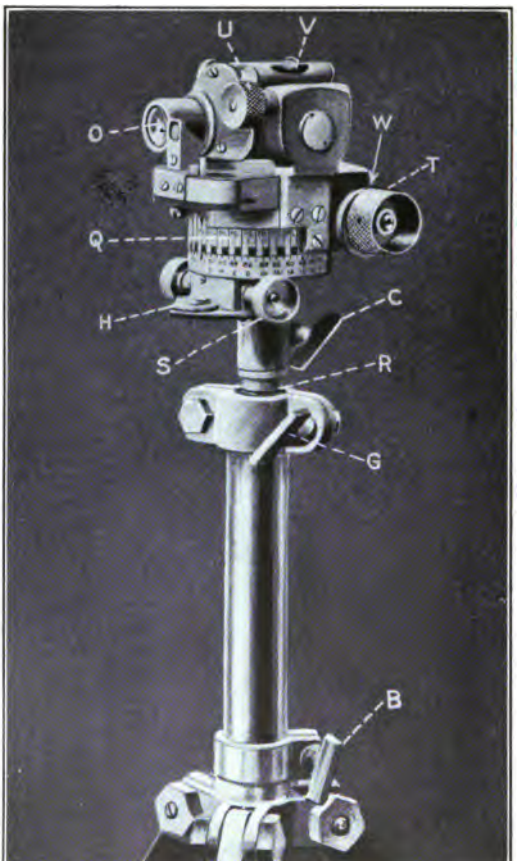

GENERAL VIEW OF COMPASS GONIOMETER.

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wire conductor, and a bulb mounted on the left upright of the telescope. The light accordingly falls on the slit of the micrometer and illuminates the scale. The light can be regulated by means of the rheostat. The bulb can be used also to facilitate the reading of angles and to illuminate the needle. In the absence of such illumination a pocket electric lamp can be used.

METHODS OF USE.

When the compass goniometer is employed as a topographic instrument only the clockwise graduations are to be used—that is, the black index mark of the upper plate, the left-hand graduations on the drum (red system of figures), the left-hand graduations on the drum (red figures from 0 to 100 mils), and the index mark Y engraved on the smooth surface.

To set up on a point.—Set the legs of the tripod in such a way that the vertical axis is over the point occupied and that the sliding tube is nearly vertical. To drive the legs into the ground, push the lower part of each leg down in line with its direction. Loosen the clamp screw of the spindle and adjust the vertical axis of rotation by bringing the bubble of the circular level to the center. Tighten the clamp screw again.

To orient the instrument at a known station by a known round of the horizon.—Let O be the known station; A, B, C, etc., other known points visible from O. Determine beforehand by means of a protractor on the map or the plane table, or by computation, the bearings α, β, γ . . . of the lines of sight OA, OB, OC . . . ; set up the goniometer on the station O; set off the angle α on the red graduations of the lower plate; loosen the clamp screw C (Pl. IV) of the general movement; set the telescope roughly in the direction A; tighten the screw C; complete the pointing on A by bringing the vertical cross hair on the point with the slow-motion screw S.

Having done this, make the round of the horizon on A, B, C, etc., closing on A without disturbing the position of the general movement.

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Let α', β', γ' be the readings. If these readings agree within 1 mil with the theoretical bearings α, β, γ, the instrument is oriented. If the differences are considerable, take the mean ϵ of the differences $\alpha-\alpha'$, $\beta-\beta'$, $\gamma-\gamma'$. By means of the slow movement turn the goniometer so as to increase all readings by ϵ. The round of the horizon as observed will then agree as nearly as possible with the theoretical round, and the instrument is oriented—that is, its readings will be bearings.

To set off the magnetic declination on the compass goniometer.—The instrument is first oriented on a known station, as explained. Then, without disturbing the general movement, its orientation is checked with the compass. For this purpose release the needle by pushing the safety lever D (Pl. III) to the left. Turn the upper plate by pressing the eccentric disk so as to bring the needle roughly opposite its zero point. Make the setting exact by means of the upper slow-motion screw. Read the corresponding bearing. Repeat three or four times the needle check and take the average of the values thus found for the bearing (declination) of the magnetic north. Note this value and set it off on the goniometer. The declination thus found is good only for a given instrument and over a small extent of territory. If a considerable move is made the declination has to be set off anew on the compass goniometer.

The declination given by maps can be used only as a very rough approximation. The axis of the telescope is only approximately parallel to the zero line of the magnetic needle. The differences between different goniometers may amount to 20 to 30 mils.

The compass goniometer of the 1917 model, the compass of which has an adjustable zero point, can be so adjusted that its declination will have a fixed value—for instance, equal to the bearing of the magnetic north given by the battle maps or derived from an isogonic chart. Let α be the angle in mils of the magnetic north with the positive ordinates of the system of squares. The axial bearing of the magnetic north then will be

$$V_m = 6{,}400 - \alpha$$

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The instrument is first accurately oriented on a known station by sights on several known points. Then, without disturbing the general movement, the reading V_m is set off on the goniometer. The needle is released and its white end is brought exactly in line with the zero mark by means of the adjustment screw, with a small screw driver. There is no need of making this adjustment unless there are in the same unit two compass goniometers which it is desired to make directly comparable.

To orient at a given station a compass goniometer set for magnetic declination.—Set up on the station. Set off on the goniometer the value of its local declination constant. Release the needle; bring the point of the needle opposite its zero by means of the general movement.

To determine the bearing of a line AB.—Set up at A and orient in the manner just described. Then, by means of the eccentric disk and of the upper slow-motion screw, set the cross hair of the telescope on the point B. The reading on the red graduations will be the bearing of B.

To measure an angle.—The value of an angle is obtained by taking the difference between the bearings of two lines, determined as is just indicated. But if there is only one angle to be measured the orientation of the instrument can be dispensed with and the operation can be simplified as follows: Set the goniometer at zero by turning the upper plate over the lower plate. Sight on the left-hand point by means of the general movement. Clamp the lower plate and sight on the right-hand point by using the eccentric disk and the upper slow-motion screw. Read the red graduations. This reading will give the angle.

To determine an angle of site.—Sight on the point so as to bring its image on the site graduation of the micrometer. Bring the bubble of the upper level to the middle. Read the angle of site on the micrometer, noting the sign.

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TOPOGRAPHIC OPERATIONS PERFORMED WITH THE COMPASS GONIOMETER.

THREE-POINT LOCATION.

A three-point location may be made either with a compass goniometer set for magnetic declination or with a goniometer only roughly set for magnetic declination. In either operation a round of the horizon should be made, starting from a clearly defined control point, sighting in succession all the points of the round, and closing on the point of departure. The error of closure must not exceed 1 or 2 mils. The magnetic needle should be read at the start and at the end to get a check on the stability of the instrument and to afford a means of determining the declination.

The station occupied should preferably be located by graphic construction on the map or on a plane table.

Three-point location with a goniometer set for declination.—The readings will consist of bearings. The lines of sight can therefore be drawn immediately on the map by means of a protractor. If the declination is accurately known and the lines of sight are not too long the point may be put at the center of the triangle of error,[1] but under other conditions the same method should be followed that is employed for a three-point location when the declination is not accurately known, as explained below.

Three-point location with goniometer not set for declination.—If the compass goniometer is not exactly set for declination a rough orientation can be made by means of the theoretical value of the declination. The bearings of the lines of sight will differ from the readings of the round of the horizon by a small constant e, still unknown. A three-point construction will locate the point and at the same time determine the constant e—that is, the declination constant for the instrument. The work may be done by any one of the following graphic methods:

1. By constructing intersecting arcs between inverted triangles of error.

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[1] This solution applies rigorously only when the station occupied lies within the triangle formed by the control points sighted.—Translator.

Through each of the known points draw with a protractor a line having a bearing equal to the reading for that point. Mark this set of lines No. 1. Examination of the triangle of error shows in which direction all the lines of sight must be revolved to reduce the triangle in size. Through the points sighted draw a second set of lines, making with the first set an angle of a round number of mils—20 or 30, for instance—in the desired direction, the same for all. Mark this second set of lines No. 2. By joining the point of intersection of two lines of set No. 1 with the point of intersection of the two corresponding lines of set No. 2 an arc is produced or rather its chord, which may be taken graphically for the arc. In this way three or four arcs are drawn. Their point of intersection is the point sought. The position of this point with reference to the lines of set No. 1 gives the value of the correction e to be applied to the goniometer readings to transform them into bearings. This same correction e, applied with its sign to the reading of the magnetic needle, will give the value of the declination constant for the instrument.

If we had not taken the precaution to orient the goniometer roughly beforehand, the correction to be applied to the readings to transform them into bearings would not be a small number but an appreciable one C. By comparing the reading of the needle with the magnetic declination, as given by the isogonic chart, an approximate value for the constant will be obtained, and this will be expressed in even multiples of 10 mils, which may be called C_o.

Thus we have:

$$C = C_o - e$$

e being the unknown value to be determined.

The construction may be made by taking for the bearings of the lines of set No. 1 the goniometer readings increased by C.

2. By constructing the intersecting arcs with dividers. (By methods commonly used with a theodolite.)

3. By construction by the Italian or Bessel method.

4. By the tracing-paper method.

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INTERSECTION AND RESECTION.

Intersection and resection are performed by means of bearings taken with some instrument set for declination or by measurements of angles with an instrument not set for declination. The construction will be executed graphically with a protractor.

TRAVERSE; RADIAL MEASUREMENTS.

Measurement of distances.—Distances may be measured with a surveyor's chain or tape (when precision is required), by pacing (for rapid operations), or by the goniometer itself, with a stadia rod.

The rod can be used horizontally, the subtended angle being then read on the drum of the goniometer, care being taken that the last movement of the micrometer hair at each setting is made against the spring, to avoid error due to backlash. If the rod has a length of exactly 2 meters, the formula will be—

$$D=\frac{2037}{l}$$

The rod may be held vertically, the angle being then read by the micrometer, but the micrometer must then be accurately adjusted; or, to state it more precisely, it is necessary to determine the constant in the formula $D=\frac{K}{l}$ for the micrometer of the instrument used and the rod used. For this purpose we measure very exactly with the tape three distances, 25, 35, and 40 meters, respectively, from the point occupied. Measure with the micrometer the three angles subtended by the rod at each of the three distances. The result will be three readings of about 80, 67, and 50 mils. Calculate the three products $D\times l$, and take the mean product for K. This preliminary determination is indispensable.

Traverse with goniometer set for declination.—Only every other station need be occupied, and the goniometer is oriented each time with the needle. The operation can also be executed with a goniometer only roughly set for declination if, in the

MONOCULAR TELESCOPE WITH THREE PRISMATIC EYE-PIECES, TYPE X (FOR FIELD USE), 1916 MODEL.

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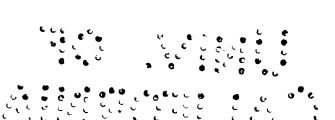

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course of the traverse, two or three distant and well-located control points can be sighted. These sights will enable us to correct the traverse in azimuth.

Traverse with a goniometer not set for declination.—Set up on every station and measure the deflection angle of each course. Be careful to record in the notebook, not the angles measured but the readings of foresights and back sights. Make a rapid sketch of the traverse as you proceed.

TELESCOPES WITH PRISMATIC EYEPIECES.

Telescopes with prismatic eyepieces are intended for use in the exploration of the terrain, the reconnaissance of targets, and the adjustment of fire. They are furnished with a micrometer, graduated in mils or in decigrads, for the measurement of small angles. The most common type in use in the artillery service has a magnifying power of 8 diameters. Others have magnifying powers of 12 and 16 diameters.

MONOCULAR TELESCOPE WITH PRISMATIC EYEPIECE.

The monocular telescope with prismatic eyepiece is intended for use in observation (chiefly at long distances) and in the preparation for fire. It has been devised as a substitute for the terrestrial telescopes of older models, the construction of which has been abandoned—the battery telescopes of the 1897–1906 models, the siege telescopes of varying magnifying power, and the telescopes for night observation.

The two principal types of monocular telescopes are described below.

Type X (for field use), 1916 model, has three eyepieces mounted on a revolving base (see Pl. V); the magnifying powers of the eyepieces are 15, 23, and 30 diameters, respectively. A joint provided with a sitometer permits angular measurements in a vertical plane. This joint is placed on a goniometer mounted on a tripod.

The features of this telescope are as follows: Magnifying powers, 15, 23, 30 diameters; actual field, 50, 36, 27 mils, approxi-

mately; eyepiece apertures 5, 3.2, 2.5 millimeters, approximately; weight of telescope without case, 3 kilograms; weight of telescope and of appliance for vertical movement, 7.5 kilograms; weight of tripod and of goniometer with case, 9 kilograms.

The sitometer and the goniometer make it possible to measure in mils the angles of site and the horizontal deflections. The micrometer is graduated in mils, the graduations being placed at intervals of 5 mils.

The magnifying power of 15 diameters is suitable for observation at twilight and at dawn, or in cloudy weather. The definition given by this magnifying power is superior to that of the night glasses. The magnifying power of 23 diameters is used for observation in bright daylight. The definition given by this magnifying power is somewhat superior to that of the extraluminous prismatic field glass, 1909 model, with magnifying power of 8. The magnifying power of 30 diameters brings out, in very bright weather, minute details at considerable distance.

Type X, for use with siege guns, 1916 model, has the same features as those of the preceding, but the goniometer is graduated in decigrads and the sitometer in degrees and minutes. The micrometer comprises a horizontal scale graduated in decigrads and a vertical scale graduated at intervals of 4 mils.

BINOCULAR TELESCOPE.

The binocular telescope (Pls. VI, VII) is an observation instrument intended especially for use in the exploration of the terrain, the reconnaissance of targets, and for fire for adjustment and effect. It is especially useful for observation at short or medium distances.

The binocular telescope can be set for either periscopic or stereoscopic observation. In stereoscopic observation the ratio of the distance between the object glasses to the distance between eyepieces is about 10.9:1 for an observer whose eyes are 65 millimeters apart. The stereoscopic effect causes distant objects to stand out very clearly.

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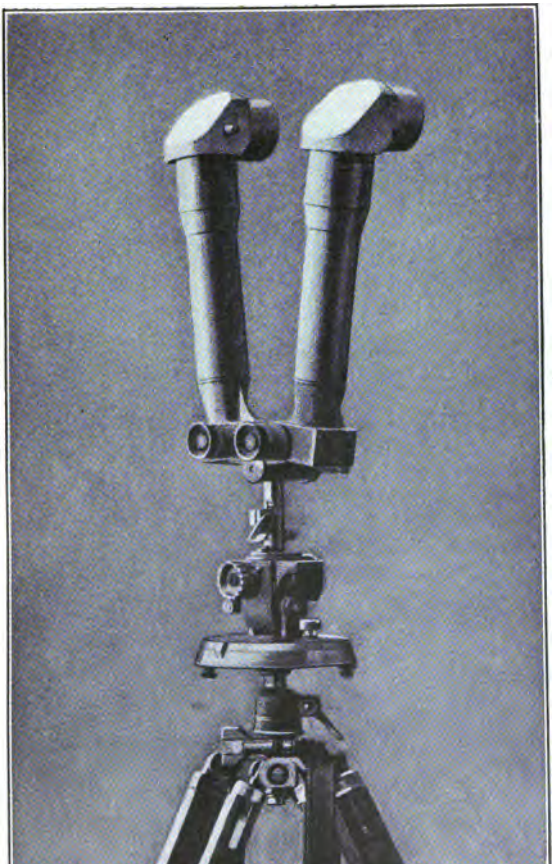

BINOCULAR TELESCOPE, TYPE D, SET FOR PERISCOPIC OBSERVATION.

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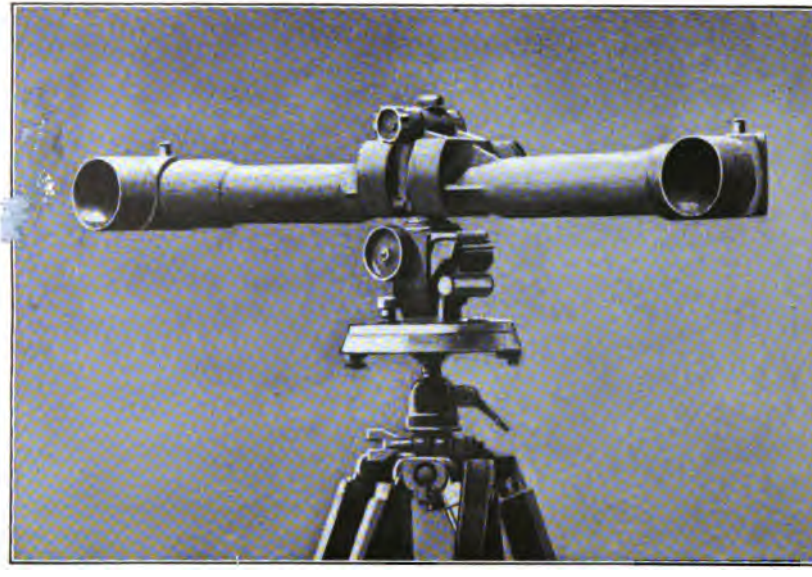

BINOCULAR TELESCOPE, TYPE D, SET FOR STEREOSCOPIC OBSERVATION.

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Types A, B, BC, C, D, E (field) of binocular telescopes are intended for the field artillery (75-millimeter gun). The goniometer is graduated in mils. It is equipped with two collimators and an adjustable level, by which it is possible to measure the angles of site in mils. The goniometer is mounted either on tripod, on the shield of the observation carriage, or on the ield of the caisson ladder. The micrometer, which is set in e straight barrel of the telescope, has a horizontal and a vertical set of graduations in mils.

The magnifying power is 16 diameters for type A, 12 diameters for types B and D, 10 diameters for types C, BC, and E. These types differ only in details of construction. The features of e D (Pls. VI, VII) are as follows: Magnifying power, 12; al field, 65 mils; eyepiece aperture, 4 mils; weight without 4 kilograms; weight with case, 7 kilograms; weight of goniometer with case, 4.5 kilograms; weight of tripod with case, 3 kilograms. This telescope will soon be mounted on the same goniometer as the monocular field telescope with prismatic eyepiece, type X.

Type DD and types F, G, H, I (heavy artillery) of binocular telescopes are intended for use at battalion headquarters and by batteries of heavy artillery. The magnifying power is 12. The goniometer has two sets of graduations, one in decigrads, the other in mils. The site graduations are in mils. The goniometer is set on a tripod, which can be used for the combined theodolite and range finder.

The micrometer in the straight barrel of the telescope is provided with a large horizontal scale graduated in decigrads, a small horizontal scale in mils, and a vertical scale in mils.

These types of telescopes differ only in details of construction. The features of type DD, for instance, are as follows: Magnifying power, 12.3; actual field, 65 mils; eyepiece aperture, 4 millimeters; weight without case, 5 kilograms; weight with case, 8 kilograms; weight of goniometer with case, 3 kilograms; weight of tripod with case, 6.5 kilograms.

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SIGHTING CIRCLE.

The sighting circle (Pl. VIII) is an observation instrument used for the same purposes as the sighting triangle. It is intended solely for measuring horizontal angles. It consists of a semicircular wooden table pivoted at the geometric center and provided with a zinc protractor graduated in decigrads or mils. A spirit level permits leveling the table.

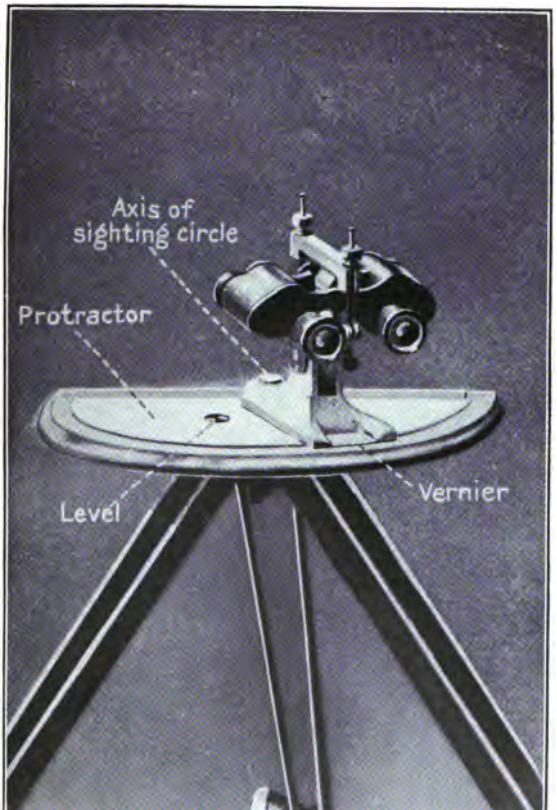
On the pivot may be placed (1) a so-called special leveling alidade—that is, an ordinary leveling alidade with a hole for the pivot and a pointer for readings on the protractor; (2) a leveling alidade with self-illuminating (radioactive) wire for night work; (3) a special alidade with electric illumination for night work; (4) a standard on which an artillery field glass may be fitted and which is provided with a vernier for deflection readings. The sighting circle can be firmly mounted on a pier of wood or masonry in an observation station. It can be installed also on a plane-table tripod head.

PERISCOPIC GONIOMETER.

GENERAL FORM AND PARTS.

The periscopic goniometer (Pl. IX) is a topographic instrument that can be used in the trenches. It is especially adapted to the use of trench artillery and is arranged solely for the measurement of horizontal angles. It consists of the following parts:

1. A goniometer mounted on a tripod similar to that of the monocular telescope, type X, 1916 model, from which it differs only in the absence of the spindle. The goniometer can be fitted, in case of need, with a monocular or binocular telescope with prismatic eyepieces. The limb is graduated at intervals of 20 mils; the deflections can therefore be read within about 5 mils. The numbers for each 200 mils (0, 2, 4 . . . 64) are double, the red series increasing in clockwise direction (as in the aiming apparatus of the 75-millimeter gun) and the black series increasing in counter-clockwise direction.



SIGHTING CIRCLE WITH PRISMATIC BINOCULAR GLASSES.

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PERISCOPIC GONIOMETER FOR USE IN TRENCHES.

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2. A periscopic telescope with prismatic eyepiece, having a magnifying power of 6 diameters, mounted on a Y-standard. It has a reticule, and its periscopic reach (distance between eyepiece and object glass) is 65 centimeters.

METHODS OF USE.

Setting up.—Loosen the clamp screws of the extension pieces of the tripod legs, and adjust the legs to the desired height by means of the screws. Drive the points into the ground by bearing down on the legs, place the goniometer on the pivot of the tripod head; tighten the clamp screw C (Pl. IX), which clamps the goniometer on the tripod. Take the Y-standard and the telescope from their case; fit the Y-standard to the goniometer; clamp it on with the clamp screw D; lay the telescope in the trunnions and tighten the thumbscrews B.

Focusing.—Sight a distant point, turn the milled rim of the eyepiece until the object is seen with the maximum clearness.

To sight a given point without measuring the deflection unscrew the clamp screw C, the goniometer will then turn freely on the pivot of the tripod. Give it the desired elevation by loosening somewhat the thumbscrew B and then tighten it again.

To measure the deflection between two points loosen the clamp F (Pl. IX) of the goniometer, turn the milled head A so as to bring the index I of the goniometer opposite the zero on the plate. Tighten the clamp F, loosen the clamp screw C, and set the cross hairs of the telescope on one of the two points whose angular deflection is to be measured. Tighten the clamp C, loosen the clamp F, and bring the cross hairs onto the second point by turning the milled head A. Read opposite the index the value of the required deflection. Remember that the divisions of the plate are at intervals of 20 mils.

TOPOGRAPHIC USES OF INSTRUMENTS OF OBSERVATION.

Any instrument with a tripod and goniometer can be used for measuring deflection angles. When it is solidly installed in a

permanent observation station its goniometer should be given a fixed orientation, so that readings made on the circle of the instrument will give, with precision and without ambiguity, the bearing desired.

Aside from their use in reconnaissance and observation, such instruments can be used in topographic work. The measurements made on the ground will have to be calculated or plotted graphically by the usual methods. In the topographic use of these instruments the following practical precautions, which also apply to observation work, must be observed:

1. The axis of rotation of the instrument must be adjusted with great precision to a vertical position.

2. In using instruments provided with micrometers (monocular and binocular telescopes) the micrometer will be used only for the measurement of small angles and never to obtain a refinement of a deflection reading made on the goniometer. For setting in direction, first point roughly with the optical axis of the instrument and then complete the setting on the deflection graduations of the goniometer.

3. With instruments furnished with two sets of graduations of the same kind in opposite directions (monocular telescope, periscopic goniometer) a single set of graduations must be used—preferably the red graduations, which increase in clockwise direction.

4. The observation notebook must always be kept with the utmost care and must contain all data and sketches, so that another officer can use the observations.

The observation instruments, being especially devised for the measurement of horizontal angles, may readily be used for intersection, three-point location, and resection.

Intersection.—Intersection is the normal method of locating targets by terrestrial observation. Simultaneous sights taken from several observation stations of known position and with properly oriented instruments can be combined for intersection.

Three-point method.—A round of the horizon made at an undetermined station on a number of control points is used to locate

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the station occupied by the three-point method. The ordinary graphic methods are used—the method of intersecting arcs, the method of triangles of error, the Italian or Bessel method, and the tracing-paper method.

If the round of the horizon is made with a very stable monocular telescope the observations are sufficiently precise to justify the computation of the position. Fixed observation stations will often be determined in this way.

Traverse and system of radial measurements.—The use of these two methods requires some one of the following means of measuring distances: (*a*) chain (or tape); (*b*) micrometer for stadia measurements (with a rod of known length); (*c*) telemeter, which can be mounted on the tripod used for most observation instruments.

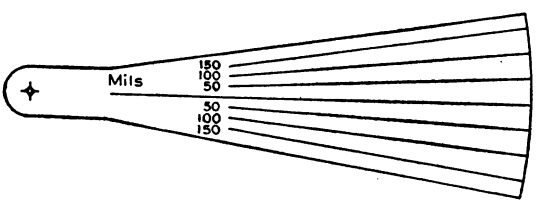

FIGURE 59.—Transparent celluloid protractor.

PARALLAX PROTRACTORS.

Parallax protractors, sometimes called target protractors, are protractors of small amplitude (100 to 200 mils), the radii of which are drawn through their entire length. These protractors are frequently used in graphic work, more especially (*a*) on plotting boards on the scale of 1:20,000, to measure the parallax of the front of the battery at the target, to measure the angular front of the target at the battery, and to measure the factors needed for the transfer of fire; (*b*) in the organization of terrestrial observation, to construct maps on the scale of 1:5,000, for the determination of the points of burst; (*c*) in the organization of the fire of a battery, to determine the parallax at a

distant aiming point on a large-scale map (1:2,000). (Railway sidings or fixed batteries.)

The range triangulation detachments issue the three types of protractors described below, graduated in mils or in decigrads corresponding to the uses mentioned above. The following remarks apply more especially to protractors graduated in mils:

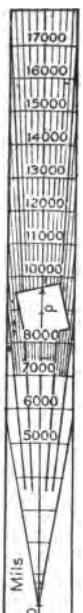

FIGURE 60.—Nontransparent protractor.

1. Transparent celluloid protractor (fig. 59). This protractor is used to measure on plotting boards on the scale 1:20,000 (or on the battle maps) the parallax, at the battery, of the front of the targets and the factors needed for the transfer of fire (the center being put on the battery), or the parallax at the target of the front of the battery (the center being put on the target). The radii are drawn at intervals of 5 mils. The outer radii are graduated in units of distance on the scale of 1:20,000. The protractor of the usual model is graduated to 17 kilometers, or 8½ kilometers if it is used for the scale of 1:10,000.

2. Nontransparent protractor (fig. 60). This protractor is used for drawing, on a large-scale map, radii from a center that lies off the map. After one of the radii has been drawn, by its bearing, for instance, the distance from a point P on this radius to the center being known, the map is placed on the protractor with the radius already drawn along the axis of the protractor. Then it is moved along the axis until the point P is at the proper graduation of the axis of the protractor (for instance, P at 8,900 meters from the center). The position is verified by placing a rule over the map and along the axis. After the map has been fixed in this position, it only remains to draw on it radii at intervals of 10 mils to the right and left of the radius already

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drawn, by connecting the two ends of each of the desired radii of the protractor. This method of procedure is especially advantageous for the rapid preparation of target sheets on the scale 1:5,000. The protractor should have a length of 5 meters if it is to be used to graduate a map on the scale 1:2,000 in bearings of an aiming point 10 kilometers away. (Organization of fire on a curved siding.)

3. Transparent protractor on tracing paper. This protractor is similar to the one just described but is on tracing paper, and it is used for the measurement of angular deflections on a large-scale map which does not include the center. The protractor is applied to the map in the same way that the map is applied to the nontransparent protractor—that is, by putting the axis of the protractor on the drawn radius of the map, so that the point P will be at the proper distance on the axis of the protractor. If a protractor of this kind is to be used for the measurement of the parallaxes of a very distant aiming point (10 kilometers away) on a large-scale map (1:2,000) it must have a length of 5 meters (organization of battery fire by the use of a very distant point).

The range triangulation detachments also issue, besides these protractors, other target protractors graduated in mils or in decigrads and marked in sections of even kilometers or in sections of odd kilometers graduated on the scale of 1:10,000.

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GLOSSARY.

Adjustment: *Réglage.* The process of correcting the elevation and deflection of the gun and the height of burst until the projectile bursts or falls at the desired point.

Aiming line: *Direction repère.* The line from gun to aiming point.

Aiming point: *Point de pointage.* The point brought, by movement of the gun, to the center of the cross hairs of the sight after the proper deflection angle has been laid off on the sight, so that the axis of the gun will point in the direction of the target, which is invisible from the gun.

Angle of elevation, *or, briefly,* Elevation: *Angle de tir.* The vertical angle between the line from gun to target and the axis of the gun when the gun is laid. *See also* Quadrant angle of elevation.

Angle of site, *or, briefly,* Site: *Angle de site.* The vertical angle between the line from gun to target and the horizontal line passing through the sight of the gun.

Angle traverse: *Cheminement d'angle.* A traverse in which the courses are not measured and which serves merely to determine the correct direction from one point to another along it.

Army: *Armée.* Several army corps.

Army corps: *Corps d'armée.* Several divisions.

Axial bearing: *Gisement.* In this book the term "axial bearing" denotes the azimuth angle reckoned in clockwise direction from the north end of the *y* axes of the system of squares shown on the maps. (See p. 27.)

Battalion: *Groupe.* Two or more batteries. The title of battalion commander is "chef d'escadron," here translated "major."

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Battle maps: *Plans directeurs.* Maps on which tactical features and units are plotted.

Bearing: *Gisement.* *See* Axial bearing.

Centesimal minute, centesimal second. Respectively $\frac{1}{100}$ and $\frac{1}{10.000}$ of a grad.

Counterslope: *Contre pente.* The slope of a hill or ridge toward the direction of the enemy. Not the counterslope of fortifications.

Documents: *Documents.* Here used, as in the French, to include maps, drawings, and papers of almost any kind. This use of the word, though not common in English, is admissible.

Elevation: *Angle de tir.* *See* Angle of elevation.

General control, general control sheets: *Canevas d'ensemble.* The skeleton or basic net of a topographic map, consisting of points determined by geodetic and other methods of surveying.

Grad: *Grade.* One one-hundredth of a right angle, of 54′.

Heavy artillery: *Artillerie lourde* (abbreviated A. L.). Heavy ordnance.

High-powered heavy artillery: *Artillerie lourde de grande puissance* (abbreviated A. L. G. P.). Very powerful heavy ordnance.

Major: *Chef d'escadron.* Commanding officer of an artillery battalion.

Mil: *Millième.* The angle (approximately) subtended by 1 meter at a distance of 1,000 meters, 2 meters at 2,000 meters, etc.

Plane table: *Planchette.* Plane table as understood by us.

Planimetric detail: *Planimétrie.* The features of the ground that are accurately located on the map.

Plotting board: *Planchette de tir.* A plane table or map designed to transform topographic data into polar coordinates for use in artillery fire. Called "artillery board" by the British.

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Polar coordinates (location by): *Rayonnement.* Location of a point by its direction and distance from another point, the position of which is known.

Quadrant angle of elevation *or* Quadrant elevation: *Angle de tir.* The vertical angle between the axis of the gun and the horizontal line passing through the gun. It is greater than the angle of elevation when the target is above the horizontal and less when the target is below the horizontal. *See also* Angle of elevation.

Range triangulation: *Canevas de tir.* A net of reference points, more closely spaced than those of the general control and intended to be used in the control of fire.

Range triangulations detachments (or groups): *Groupes des canevas de tir.* Detachments charged with making the range triangulation.

Reference point: *Point de repère.* A point to which a horizontal or vertical direction is referred. In speaking of the horizontal direction of fire (deflection) this point is called an "aiming point" (point de pointage).

Site: *Site.* Elevation of the target above or depression below the gun. Sometimes used as an abbreviation for "angle of site." Some French guns are provided with an elevating device (independent line of sight) by which allowance can at once be made for the site of the target. This device is independent of that by which the angle of elevation is set off, and it enables the laying to be done more rapidly.

Soundings: *Sondages.* Atmospheric data obtained from kites or balloons carrying self-registering instruments.

Three-point method: *Relèvement.* A mode of topographic surveying. The number of points is not restricted to three.

Topographic range (or distance): *Distance topographique.* The range obtained from the map or by topographic methods, so called to distinguish it from the range that corresponds to the elevation given to the gun in order that the projectiles may hit the target; that is, the "range-table range corresponding to the corrected quadrant angle of elevation."

ABBREVIATIONS USED ON THE STAFF MAPS (CARTES DE L'ÉTAT-MAJOR).

In abbreviations made up of the first and the last letter or letters of a word, the last letter or letters are printed in smaller type above the line. By this means the terms indicated by two similar abbreviations can be distinguished. Thus Sal is the abbreviation for Saline, but S^{al} is the abbreviation for Signal.

Abat.	Abattoir.	Slaughterhouse.
Ab^{be}.	Abbaye.	Abbey.
Abr.	Abreuvoir.	Watering trough.
Aig^{le}.	Aiguille.	Needle (pointed summit of mountain) or pinnacle.
Anc^{n}.	Ancien.	Ancient, former.
Aqu^{c}.	Aqueduc.	Aqueduct.
Arb.	Arbre.	Tree.
Ard^{re}.	Ardoisière.	Slate quarry.
A^{t}.	Arrêt.	Railroad station.
Ars^{l}.	Arsenal.	Arsenal.
Art^{n}.	Artésien.	Artesian well.
As^{e}.	Asile.	Asylum.
Aub^{ge}.	Auberge.	Tavern.
Av^{ue}.	Avenue.	Avenue.
B.	Bois.	Wood (woodland).
Bac.	Bac.	Ferryboat.
Bat.	Bateau.	Boat.
Bat^{ie}.	Batterie.	Battery.
B^{che}.	Bouche.	Mouth of river.
B^{de}.	Borde.	Farm.

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B^{g}	Bourg	Town.
B^{ide}	Bastide	Small country house in southern France.
B^{ie}	Bergerie	Sheepfold.
B^{in}	Bassin	Basin.
Bl	Blockhaus	Blockhouse.
B^{ment}	Bâtiment	Building.
B^{ne}	Borne	Boundary mark.
B^{on}	Buisson; buron	Thicket, patch of woodland, hut or cabin.
B^{que}	Baraque	Hut.
B^{re}	Barrière	Gate.
Briq^{ie}	Briqueterie	Brick kiln.
C	Cap	Cape (headland).
Cab^{et}	Cabaret	Drinking place, saloon.
C^{al}	Canal	Canal.
C^{ade}	Cascade	Waterfall.
Car^{re}	Carrière	Quarry.
Carre^{fr}	Carrefour	Crossroads.
Cas^{ne}	Caserne	Barracks.
Cath^{le}	Cathédrale	Cathedral.
Cay^{r}	Cayolar	Kaolin pit.
Ch^{au}	Chateau	Chateau.
Ch^{ée}	Chaussée	Road, causeway.
Ch^{et}	Chalet	Chalét.
Ch^{in}	Chemin, Chemin de fer.	Road, railroad.
Ch^{lle}	Chapelle	Chapel.
Ch^{née}	Cheminée	Chimney.
Cim^{re}	Cimetière	Cemetery.
Cit^{e}	Citerne	Cistern.
Cit^{lle}	Citadelle	Citadel.
Cl^{er}	Clocher	Belfry, steeple.
C^{ne}	Cabane	Hut.
Colomb^{r}	Colombier	Dovecote.

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Co^{n}	Coron	Miner's dwelling.
Couv^{t}	Couvent	Convent.
Cr^{e}	Calvaire	Wayside cross.
Cr^{x}	Croix	Cross.
C^{se}	Cense	Farmhouse, farm.
CT	Canton	Canton (territorial subdivision).
Deb^{re}	Débarcadère	Landing place.
Déf^{é}	Défilé	Mountain pass.
Dép^{t}	Département	District.
Dig	Digue	Dike, dam.
Dist^{le}	Distillerie	Distillery.
D^{ne}	Douane	Customhouse.
Dom^{e}	Domaine	State property.
Dunes	Dunes	Dunes.
E	Eau	Water.
Éc^{le}	Écurie	Stable.
Éc^{se}	Écluse	Lock, sluice.
Ég^{se}	Église	Church.
É^{le}	École	School.
E. M	Eau minérale	Mineral spring.
Emb^{re}	Embarcadère	Wharf, pier.
Emb^{ure}	Embouchure	Mouth (of river), entrance (to harbor).
Étab^{nt}	Établissement	Establishment, institution.
Ét^{g}	Étang	Pond.
Ét^{le}	Étoile	Point of junction of several roads or trails.
Fab^{e}	Fabrique	Factory.
F^{bg}	Faubourg	Suburb.
F^{e}	Ferme	Farm.
F^{ge}	Forge	Smithy.

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Fl	Fleuve	River.
Fme	Ferme	Farm.
Fne	Fontaine	Fountain, spring.
Fondre	Fondrière	Bog.
Fontne	Fontaine	Fountain, spring.
Fortif	Fortification	Fortification.
Fr	Four	Furnace.
Frie	Fonderie	Foundry.
Fsé	Fossé	Ditch.
Ft	Forêt, fort	Forest, fort.
Galie	Galerie	Gallery.
Gd	Grand	Great, large.
Gge	Grange	Barn.
Gler	Glacier	Glacier.
Grd	Grand	Great, large.
Grge	Gorge	Gorge.
Grte	Grotte	Grotto.
Gué	Gué	Ford.
Habt	Habert	Cow barn or shed.
Hal	Hôpital	Hospital.
Ha	Hameau	Hamlet.
He	Halte	Halt.
Hel	Hôtel	Hotel, large house, or public building.
Hermge	Hermitage	Hermitage.
Hie	Haie	Hedge.
Hosp	Hospice	Hospice.
Hydr	Hydraulique	Hydraulic.
Î	Île	Island.
Irrig	Irrigation	Irrigation.
Je	Jetée	Jetty.
~in	Jardin	Garden.

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L.	Lac	Lake.
Lag.	Lagune	Lagoon.
L^{de}.	Lande	Moor, waste land.
L^{r}.	Lavoir	Washhouse.
L^{te}.	Lette	Swamp (?).
Loc^{re}.	Locature	Farmhouse (?).
M.	Mas.	Farm.
Mag^{in}.	Magasin	Magazine, storehouse.
Mal^{rie}.	Malterie	Malt house (for brewing).
Manuf^{re}.	Manufacture	Manufactory.
Mare.	Mare.	Pool.
Mar^{ge}.	Marécage.	Marsh.
M^{che}.	Marché.	Market.
Mét^{rie}.	Métairie	Small farm.
M^{gne}.	Montagne	Mountain.
M^{in}.	Moulin.	Mill.
Mine.	Mine	Mine.
M^{on}.	Maison	House.
Mon^{t}.	Monument	Monument.
M^{t}.	Mont.	Mount, mountain.
Mul^{r}.	Muletier (sentier)	Mule path.
Mur.	Mur.	Wall.
Nat^{l}.	National	National.
Navig.	Navigable	Navigable.
N. D.	Notre Dame	Notre Dame (Our Lady).
Obs^{re}.	Observatoire	Observatory.
Orat.	Oratoire	Oratory.
Ose.	Oseraie	Osier ground.
Ouvr.	Ouvrages extérieurs	Outworks.
P.	Pont	Bridge.
P.	Parc (à bestiaux)	Park for cattle.
P.	Pic	Peak.

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Pap^{ie}	Papeterie	Paper mill.
P^{au}	Poteau (indicateur)	Guide post.
P^{eau}	Ponceau	Culvert.
Pêch^{ie}	Pêcherie	Fishery.
Pép^{re}	Pépinière	Nursery (of plants, etc.).
P^{ge}	Passage	Passage.
Ph	Phare	Lighthouse.
Pil^{r}	Pilier	Pillar.
Plâtr^{re}	Plâtrière	Plaster quarry or kiln.
Pla^{u}	Plateau	Plateau.
Pl^{on}	Plantation	Plantation.
Polyg	Polygone	Proving ground, range, drill ground (artillery).
Po^{nt}	Point	Point.
P^{t}	Port	Port, harbor.
P^{t}(^{e})	Petit	Little.
P^{t}	Pont	Bridge.
P^{te}	Porte	Gate.
P^{te}	Poste	Post (mail).
P^{te}	Pointe	Extremity, headland.
Poud^{ie}	Poudrerie	Powder mill (manufactory).
Pr	Praine	Meadow.
P^{on}	Prison	Prison.
P^{ts}	Puits	Well.
Q^{r}	Quartier	Quarter.
R	Rivière	Stream, river.
R	Rue	Street.
Raf^{ie}	Raffinerie	Refinery.
R^{au}	Radeau	Raft.
Rav	Ravin	Ravine.
Red	Redan	Redan.
Red^{e}	Redoute	Redoubt.
R^{er}	Rocher	Rock.

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Retr^{nt}	Retranchement	Intrenchment.
Rig	Rigole	Trench, gully, rivulet.
R^{ise}	Remise	Coach house (wagon shed).
Roub^{ne}	Roubine	Outlet of salt marsh to the sea.
R^{ne}	Ruine	Ruin.
R^{te}	Route	Road.
R^{voir}	Reservoir	Reservoir.
S	Sous	Under.
Sabl	Sablière	Sand or gravel pit.
Sal	Saline	Salt works or salt mine.
S^{al}	Signal	Signal.
Salp^{re}	Salpêtrière	Quarry where niter may be found.
Sanat	Sanatorium	Sanitarium.
Sap^{re}	Sapinière	Fir wood.
S^{ce}	Source	Spring.
Scie	Scierie	Sawmill.
Sémin	Séminaire	Seminary.
Sentier	Sentier	Path.
Som^{t}	Sommet	Summit.
S. P	Sous-préfecture	Subprefecture.
St, St^{a}, St^{on}	Station	Station (railroad).
Suc^{ie}	Sucrerie	Sugar mill.
Susp	Pont suspendu	Suspension bridge.
Syn^{e}	Synagogue	Synagogue.
Tan^{ie}	Tannerie	Tannery.
T^{el}	Tunnel	Tunnel.
Tél^{e}	Télégraphe	Telegraph.
Temp	Temple	Protestant church.
T^{ie}	Tuilerie	Tile works.
T^{nt}	Torrent	Torrent.
Tomb	Tombeau	Tomb.

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T^{r}	Tour	Tower.
Tr	Tramway	Tramway, street railway.
Tr^{l}	Treuil	Windlass.
Us^{e}	Usine	Factory, works.
Vac^{le}	Vacherie	Cow house (cow barn or shed).
Val^{on}	Vallon	Small valley.
V^{duc}	Viaduc	Viaduct.
$V^{ée}$	Vallée	Valley.
Ver	Verger	Orchard.
V^{ge}	Vièrge	Virgin.
V^{ge}	Village	Village.
Vigne	Vigne, Vignoble	Vineyard.
V^{on}	Vallon	Valley (small), dale.
V^{x}, V^{lle}	Vieux, Vieille	Old.

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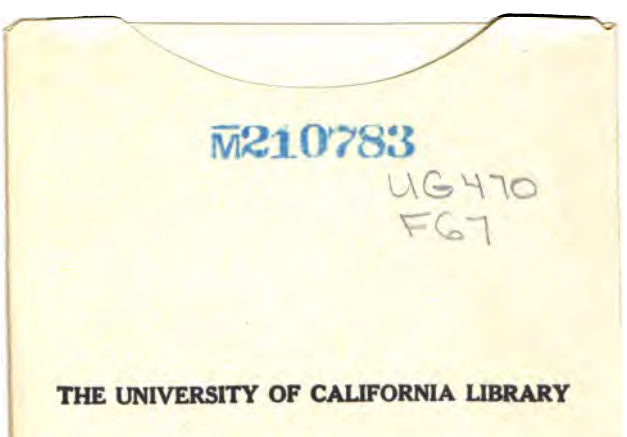

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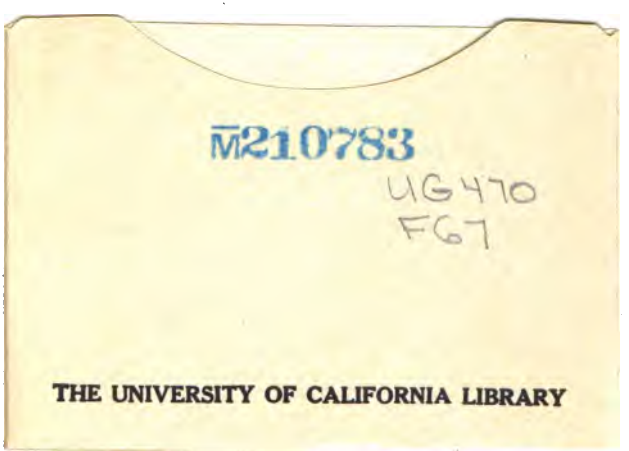

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